science and scientists in India

NEM KUMAR JAIN

SCIENCE AND SCIENTISTS IN INDIA
(Vedic to Modern)

Science and Scientists in India
(Vedic to Modern)

NEM KUMAR JAIN, M.Sc.,
P.G.D.A.V. College,
University of Delhi.

৪২৯

[Illustrated]

UBSPD

UBS Publishers' Distributors Ltd
8/1-B, Chowringhee Lane, Calcutta-700 016
Ph:212451, 249473

INDIAN BOOK GALLERY
2691, Gali Baradari, Ballimaran,
Delhi-110006

ACC NO-16352

First Edition 1982

© **Jain,** Nem Kumar 1980

Published by Indian Book Gallery, 2691
Gali Baradari, Ballimaran, Delhi-110006
and printed by Aruna Printing Press,
B-78, Naraina Industrial Area, Phase II,
New Delhi-110028.

To My Mother

Contents

Page

Acknowledgements ix

Prologue xi

1. *Creation of the Universe*
Creation of the Universe; Classical Views : Vedic View; Sankhya Philosophy; Modern Views : Ptolemy, Copernicus, Newton, Kant; The Big-Bang Theory; Age of the Universe : (a) On the basis of Ancient Indian Astronomy, (b) Modern Scientific Evidences. 1-9

2. *The Earth*
The Earth; The Descent of Man on the Earth, The Evolutionary Time-Table, Chart of Primate Evolution, Some Recent Clues; Early Civilization. 10-15

3. *Science in India*
Pre-Science; Science ; Science in Ancient India; Scholars' Views on Science in India : Max-Mullar, Lenin, Laplace, Einstein, Goldstucker, Mecdonell, J.D. Bernal, J. Barden; Indians Enlightened the Greeks and the Europeans; Mathematics and Astonomy in India : Bakhshali Manuscript, Baudhyana Sulba-Sutra, Ancient Astronomy, Aryabhata and his Aryabhatia, Varahmihira and his Panchsidhanta, Mathematics; Chemistry in India : Alchemy, Ancient Chemistry; Medicinal and Biological Sciences : Beginnings of Biology, Biology in India; Ancient Indian Classification of Animals; Indus Valley civilization; The Great Centres of Learning : Taksashila and Nalanda Vishvavidyalaya; The decline of Indian Science; Revival of Scientific Studies; Brain-Drain; India, Emerging Scientific; Indian Approach to life. 16-69

4. *Scientific Method*
Nature of Science; Historical Development : Ancient Indian Scientific Methodology; Modern Scientific Method. 70-79

5. *Some Eminent Indian Scientists*
Sir J.C. Bose; S. Ramanujan; Meghnad Saha, Sir C.V. Raman; H.J. Bhabha; D.S. Kothari, Jayant Narlikar; Sir P.C. Ray; S.S. Bhatnagar; T.R. Seshadri; Raja Ramanna; M.S. Swaminathan; Birbal Sahni; Panchanan Maheshwari; Atma Ram. 80-124

6. *Science and Dharma* 125-128

7. *Impact of Science on Modern Life*
Importance of Science; Scope of Science; Applications of Science; Horrors of Science; Limitations of Science; Human Happiness. 129-138

8. *Scientific and Technological Developments* 139-154

Bibliography 155-159

Index 160-163

Corrigendum

Acknowledgements

Apart from acknowledgements made at various places in this book, I am highly grateful to Professor D.S. Kothari, Former Chairman, University Grants Commission who has encouraged and guided me in my studies on general science. Thanks are also gratefully offered for the discussion, criticism and other help given by the following :

Professor G.S. Paliwal, Head of the Department of Botany, Garhwal University; Prof. B. Saran, Head, DESM, NCERT; Dr. K.L. Srivastva, Scientist, ICAR and Dr. A.K. Bag, INSA; Dr. U. Sinha, Reader, Botany Department, Delhi University; Dr. V.B. Bhatia, Reader, Physics Department, Delhi University.

I am also beholden to my friends Shri S.K. Sharma, Shri Gopal Krishna, Shri S.C. Bhatia and Dr. N.K. Gautam each one of whom has gone through a part of the manuscript and offered suggestions for the improvement of the same.

To my wife Pushpa, I have special words of appreciation for sparing me from household problems and taking upon herself the drudgery of isolation for innumerable hours which rightly belonged to her.

AUTHOR

Prologue

There is felt a necessity for evaluating the contribution of *Bhartiya Darshan* (Indian Thought) to the field of science. This concerns India—its culture and its people, and more precisely SCIENCE AND SCIENTISTS IN INDIA.

The archaeological excavations in India since 1920, have proved beyond doubt that Indian civilization is one of the oldest one. The Indians were highly developed when people in the west were just learning how to speak. It is definitely known that the Indian sciences had developed and achieved great eminence when Europe was passing through the dark period of early middle ages. A long period of invasion beginning with the Greeks, the Scythians, the Huns, the Mugals and closing with the Britishers, deprived India not only of its wealth but also of its knowledge. But all this could not destroy India. Today, India is the world's third largest scientific community. India was the fourth among all the countries that supplied experts of international fame to the United Nations Development Programme (UNDP) in 1975. America alone is taking every year many thousands of qualified Indians. India is the fourteenth largest country so far as the output in scientific literature is concerned. This work is for the improvement of the above position and is expected to help the scientific environment by encouragement and infusing confidence in the Indian minds.

This book starts from the question of the creation of the universe, then traces the growth of Science in India, describes the life and works of many Indian scientists, richness of India and its culture, development of scientific methodology, science and *dharma* and the impact of science on modern life. This will not only trace the growth of Science in India, but also give a glimpse of the labour put in by numerous Indian scientists.

Few books have been written on Science in India, mostly by non-scientists. Such writers might be scholars of Vedic literature/history/

culture, but it seems that they have not done full justice to the scientific presentation of the many noble ideas that originated in India. One must discuss the relevance of scientific ideas in ancient texts, in the light of developed form of science. As a student of science, I have tried to discuss the subject in the most proper dimensions. To make the book more authentic, I have stated wherever necessary, the important events, discoveries and quotations from the original documents.

During the preparation of this book, a part of my views herein, has been published in the form of about twenty-five articles in many popular and professional Indian and Foreign journals.

This book has been written primarily for the non-specialist readers in general and science readers in particular, to provide information on various aspects of science in India. It can serve as a supplementary material for the general Science courses of many universities. The material of the book if made available to any reader of whatever calibre, will enlighten him and may kindle his intellect in many directions.

N. K. Jain

1

Creation of the Universe

The problem of the origin and the extent of the universe has attracted the attention of the philosophers from times immemorial. Is it evolution or creation ? Many speculations have been made so far. But the scientists have not been able to solve these. The concept of 'Creation of the Universe' is scientifically unsound. Creation out of what? Making something out of nothing is a hypothetical absurdity, *Gita*, 2-16 says:

नासतो विद्यते भावो ना भावे विद्यते सतः ।

meaning what does not exist cannot come into existence and what exists canot be destroyed.

This is what we call today 'Law of Conservation of Mass (Energy)'

In fact there is no such thing as Creation of the Universe, it is manifestation. This can be understood from the story of Existence of the Universe, in the hymn of the *Rigveda*, X, 129, the most sublime one in the entire vedic revelation. The word 'creation' must not be used in the sense of making something out of nothing but rather as making something shapely out of shapelessness.

Classical Views

Vedic View: According to Vedas from the primordial state of *Prakriti* or primeval matter, the universe assumed multifarious shapes covering 4,32,0000,000 years. This was called Brahma's day or *Kalpa*. Then for a similar duration, all matter underwent a gradual process of dissolution, returning to the original primordial state. This was called Brahma's night. The end of the dissolution process was called '*Pralaya*', These ideas resemble somewhat to the modern big-bang theory of creation of the universe.

According to the laws of Manu, the ether (*Akash*) engenders the atmosphere; the atmosphere transforming itself brings about light; the atmosphere and light giving rise to heat, produce water, and water is the source of all creatures. It shows that chance played no part in the manifestation process. The entire existence was governed by a definite law.

Before looking at the process of manifestation of the universe, it should be understood that the process is so vast, complex and incomprehensible that it can neither be borne by any personal evidence nor can it be known completely to the wisest sage or scientist. Two vedic *mantras* could be cited in this direction:

को अद्धा वेद क इह प्रवोचत् कुत आजाता कुत इयं विसृष्टिः ।
अर्वाग्देवा अस्य विसर्जनेन आथा को वेद यत आ वभूव ।।
Rigveda, X, 129, 6.

'Who verily knows and who can here declare it, whence it was born and whence came this varied creation? The learned sages were born after this world's creation. Who knows then, whence it first came into being?'

इयं विसृष्टिर्यतः आवभूव यदि वा दधे यदि वा न ।
योऽस्याध्यक्षः परमे व्योमन्त् सो अंग वेद यदि वा न वेद ।।
Rigveda, X, 129, 7.

He (God), the first origin of this creation upholds it, He is the supervisor of even the highest heaven, He verily knows it and who knows it, if He also does not know.

The comprehensive survey about the question of manifestation of the universe is given in *Nasadiya sukta* of the *Rigveda* tenth mandal and 129th hymn:

नासदासीन्नो सदासीत्तदानीं नासीद्रजो नो व्योमा परोयत् ।।

It holds that there was primordial chaos in the beginning; there was neither the *Asat* (the manifested cosmos) nor the *sat* (first state of matter evolved out of primordial matter for creation of the universe) nor were these nebulae धुँध nor the sky beyond them.

किमावरीवः कुहमस्य शर्मन् अम्भः किमासीद गहनं गभीरम् ।।
न मृत्युरासीदमृतं न तर्हि न रात्र्या अह्न आसीत् प्रकेतः ।।
आनीदवातं स्वधया तदेकं तस्माध्दान्यन्न परः किं चनास ।।

What did then exist? The vedic sage answers: 'There was something which covered all, like a haze involved in a huge and unbounded collapse. There was no death, nor immortal life, there was no night nor day; God alone Himself breathed, although no wind existed by His own inherent Might.'

Kapila's Sankhya Philosophy: The *Sankhya Sutras* about creation of the universe were propounded by Kapila Muni. The word *Sankhya* means number, pertaining to enumeration, perfectness and reality. So the *Sankhya* philosophy means perfect knowledge or wisdom. This philosophy possesses a unique interest in the history of thought embodying the earliest clear and comprehensive account of the process of cosmic evolution, viewed not as a mere speculation but a positive principle based on the conservation, transformation and dissipation of energy. According to *Sankhya* philosophy, the universe evolved out of an unmanifested, undifferentiated, infinite and eternal primordial ground termed *Prakriti*. This is made up of three basic entities (*gunas*):

(1) *Sattva* or Essence or Intelligence—stuff, which has the property to manifest something to the senses. This serves as a medium for the reflection of Intelligence.

(2) *Rajas* or Energy, which is efficient in a phenomenon and is characterised by a tendency to do work or overcome resistance.

(3) *Tamas* or the matter, which is characterised by the property of inertia.

All these *gunas* exist in a state of uniform diffusion and equilibrium in *prakriti*. The tendency of the energy to do work is counteracted by inertia of the matter and so the nature of *prakriti* is maintained. Evolution began when God caused a disturbance in this state of equilibrium. In the first stage of creation, by the action of energy on matter, an inert material called *bhutadi* was created which was devoid of any other property except mass. In the second stage, from *bhutadi* appeared five different kinds of *tanmatras*, the entities charged with various kinds of energies. These energies endowed upon *tanmatras* certain characters such as sound, touch, colour, taste and smell; only one character being on one *tanmatra*. In the third stage, there occurred the formation of five different perceptible gross elements called *bhutas* viz. *akasa* (ether), *vayu* (air), *teja* (fire), *apa* (water) and *kshiti* (earth). As English language is inadequate to translate these words, the words in the brackets have been chosen to give approximate meanings. For instance earth, water and air have been used for *kshiti*, *apa* and *vayu* which mean all solids, all liquids and all gases respectively. These *bhutas* are composed of different kinds of *anus*. The *anus* are the particles which are obtained when a thing is divided and subdivided until further division is not possible.

The five physical elements ether, air, fire, water and earth had respectively the specific and characteristic properties of sound, touch, colour, taste and smell. The vast variety of substances all belonging to the same gross element are the result of the differences in the attachment of various *gunas* and *tanmatras* in them. That is how an infinite variety of world objects resulted from infinitely varied combinations of these basic *gunas*. The *gunas* are always uniting, separating and uniting again making cosmic evolution a two fold process—creation(expansion) as well as destruction (contraction).

Now let us look at the ancient Indian views in the light of modern developments. The earliest cosmic mass in the vedic terminology in known as अप्रकेत सलिलम (*Rigveda*, X, 129, 3) which is almost the same as 'primeval atom'—a highly compressed, extremely rarefied and completely homogeneous state, from which the universe started its evolutionary process, in the words of Belgian astronomer, George Lamaitre. Modern physicists are inclined to introduce a better term as 'primeval nucleus.' It may be noted that the word सलिलम is not water as is popularly understood and translated, but has a technical meaning, in the vedic terminology, a close resemblance to the 'primeval nucleus' of modern science, in which the ordinary matter did not count and the primary role was played by 'intensely hot radiations'.

Regarding the size of universe the vedic view is that the entire universe is finite and is enveloped by *Prakriti*. *Brahaman* alone is infinite.

इन्द्रियेभ्यः ह्यार्थां अर्थेभ्यश्च परं मनः
मनसस्तु परा बुद्धिर्बुद्धेरात्मा महान् परः ।।
महतः परमव्यक्तात् पुरुषः परः
पुरूषान्न परं किंचित् सा काष्टा सा परा गतिः ।।

(Higher indeed than the senses are their objects; higher than their objects is the mind and intellect; higher than the mind, higher than intellect is the *Maha-tattva*. Higher than this great one, is the unmanifested; and higher than the unmanifested is the infinite God—higher than that is nought).

Universe is spherical is categorical from, 'Einstein's finite, spherical universe. 'It is possible to compute the size of the universe. In order to determine its radius, however, it is first necessary to ascertain its curvature' (*The Universe and Einstein*, p. 105).

Despite the idea that the universe is vast and incomprehensible, for facility of mathematical calculations, the scientists have assumed that visible universe is a sphere and have determined its radius as 15 billion light years.

Modern Views

The Ptolemic Geocentric theory which had since long got all religious sanctions, received the first blow at the hands of Copernicus. in 1543. Copernicus' new system of the world placed the sun at the centre of the universe and ascribed three motions to the earth : a daily spin on its axis, an annual orbit round the sun, and a gyration on the earth's axis of spin to account for the precession of the equinoxes. Copernicus worked out many planetary motions mathematically. Galileo supported Copernican theory. The Milky Way was shown by Galileo's telescope to consist of innumerable faint stars. At about the same time Kepler established the three laws of planetary motions.

Newton's View: In AD 1692, Newton said, 'It seems to me that if the matter of our sun and planets and all the matter of the universe were evenly scattered throughout all the heavens, and every particle had an innate gravity towards all the rest, and the whole space throughout which matter was scattered was finite, the matter on the outside of the space would, by its gravity, tend towards all the matter on the inside, and by consequence fall down into the middle of the whole space, and there compose one great spherical mass. But if the matter were evenly dispersed throughout an infinite space, it could never convene into one mass, but some of it would convene into one mass and some into another, so as to make infinite number of great masses, scattered at great distances from one another throughout all that infinite space. And thus might the sun and fixed stars be formed, supposing the matter were of a lucid nature.'

Kant's view: In AD 1755, Kant followed Newton by regarding a limitless chaotic primordial matter as the raw material of which the universe has been formed. He supposed gravity to be the agency through which this formation took place. He thought that, as a result of mutual gravitational attractions, primeval atoms continually fell in upon one another and so became hotter. He said that the collisions of these atoms generated not only heat but also rotation. During the collisions of the atoms with nebula it got not only hotter and hotter, but also began to rotate and spun faster and faster until at last splashes of matter were thrown off from its equator. These splashes of matter formed a rotating ring which encircled the nebulae just as Saturn's rings encircle Saturn. Such rings finally condensed into planets and by many repetitions, the sun's family of planets was born. Laplace, in AD 1796, improved upon Kant's cosmogony.

J. Herschel (AD 1792-1871) confirmed with the help of his large telescopes that our solar system was a tiny part of our galaxy and there were innumerable galaxies in the universe. After this, really began the search for the origin of the universe.

While formulating models of the universe, it is usually assumed that the universe appears the same whenever and in whatever direction one might look, that is, the universe is homogeneous and isotropic in space. After this, one can proceed in either of the two ways; (i) assume that the universe is isotropic in time also, that is, the universe today is exactly the same as it was billions of years ago and shall be billions of years hence; (ii) assume that the universe began at a certain moment of time (the big-bang) and is evolving since then. The first case is that of a steady state universe and the second is that of an evolving universe.

The big-bang Theory: All the distant galaxies seem to conform to the first ever truly cosmological law that Hubble discovered in AD 1929. He found that spectral lines emanating from all the distant galaxies are shifted towards the red-end of the spectrum. It was earlier known that a red-end shift of spectral lines of a celestial object means that it is receeding from us at a speed proportional to the magnitude of the shift. Thus he concluded that many of the galaxies are moving away from us and this expansion of the universe may be expressed mathematically as $V = HR$ *(Hubble's Law)*, Where V is the recessional velocity of a galaxy at a distance R and H is a Hubble's constant.

Hubble plotted his observations and from the graph concluded that any galaxy, at a distance d million light years, receedes with a velocity of 19 d miles per second

$$R = 10^6 d \text{ light years}$$

$$= 10^6 \times 365 \times 24 \times 3600 \times 186000 d \text{ miles}$$

and $v = 19 \text{ d miles per second}$

$$1/H = R/V = 10^6 \times 365 \times 24 \times 3600 \times 18600/19 \times d$$

$$= 9.7 \times 10^9 \text{ years} = 10 \text{ billion years}$$

Also R/V is the time taken by any galaxy to move from the initial position to the present position. This means at a time T given by $R/V = 1/H = \text{constant}$, all galaxies must have been in the same place, perhaps in the form of an extremely dense sphere of gas (mass). Thus our universe must have originated from a state of unimaginably dense concentration of matter in which all galaxies were packed at a definite epoch of time some ten billion years ago. In view of the recent data and using latest observational techniqes, this calculation of the age of the universe is turning out about 14 billion years. Some process triggered at the initial exposition, the fragmentation of this ball (the dense concentration of galaxies)—the so called big-bang took place—and the fragments (as in a bursting rocket) started flying away from one another. These fragments later on condensed into galaxies.

Before we can draw final conclusions about the creation of the universe, much remain to be done. Some eminent scholars are still conducting research in this field and so the final theory is yet to take shape. Man is certainly approaching his long cherished goal—to unfold the mystery of the universe.

Age of the Universe

Let us examine how old is the universe. This needs a review of the various modes adopted so far for calculating the 'Age of the Universe'. It will be shown that the mode adopted by the Hindu sages to arrive at the age of the universe is remarkably close to the age independently arrived at by different techniques of modern science.

Age of the Universe based on Ancient Indian Astronomy: According to the Hindu calculations, our creation (more accurately speaking Expansion/Contraction process) consists of Fourteen *Manus*. One *Manu* is Seventy one *chaturyugas* or *Mahayugas*, each of which means 43,20,000 years as under:

Krta or Satya Yuga	(Golden Age)	17,28,000 years
Treta Yuga	(Silver Age)	12,96,000 years
Dwapar Yuga	(Bronze or Copper age)	8,64,000 years
Kali Yuga	(Iron Age)	4,32,000 years
	Total	43,20,000 years

One Manu = 71 Chaturyuga = 43,20,000 × 71
= 30,67,20,000 years

At the present stage of expansion, we are in the seventh *Manu* (called *Vaivasvata Manu* विज्ञानमानन्दम्:) and Twenty eight *Chaturyuga* where 5079 years of *Kaliyugn* have passed* (*Kaliyuga* started at midnight between Feb 17 and 18, 3102 BC). at the meridian of Ujjayini.

The years passed in = 30,67,20,000 × 6
= 1,84,03,20,000

In the 28th cycle (out of the total of 71) of the *Chaturyuga*, 5079 years of the *Kaliyuga* have passed, so the remaining are
43,20,00 − 5079 = 4,26,921 years

Period passed (of seventh *Manu*) = 43,20,000 × 28 − 4,26,921
= 12,09,60,000 − 4,26,921 years
= 12,05,33,079 years

Age of Expansion (Creation) of the universe = 1,84,03,20,000 + 12,05,33,079 years
= 1,96,08,53,079 years

Modern Scientific Evidences (About the age of the Universe): (i) According to Prof. George Gamow, 'Astronomical evidence clearly indicates that the multitude of stars we see in the sky—our own Sun among them—could not have existed eternally and were probably formed earlier than some two billion years ago from the hot primordial gas that previously filled all the universe.'

(ii) *Geological Evidence:* Radio-active-clock-method was applied by modern geologists to arrive at the age of the rocks that form the crust of our globe, and it was found that the crust of the Earth (oldest mineral, uranite) is at least two billion years old.

* *A Concise History of Science in India*, D.M. Bose, INSA.

(iii) *From the Evidence Yielded by Oceanic Waters:* The famous scientist Edmund Hally based his observations on the salinity of ocean water which is 3%, and for this calculation, the scientist believes, the rivers must have been at work for about 3 billion years.

(iv) *Stellar Resources:* By making use of the relation between stellar masses and stellar life spans, scientists have concluded that most of the stars forming the milky way system were born about three billion years ago.

(v) The use of latest observational and statistical techniques have enabled E.P. hubble and others to state that the age of the universe is Fourteen billion years. Studies based on luminosity and Einstein's Theory of Relativity, support his figure.

Thus we see that whenever we ask questions about the age of some particular part or property of the universe, we always get the same approximate answer: a few billion years. This rejects the idea of a permanent unchangeable universe.

2

The Earth

Regarding the creation of the earth, Prof. George Gamow says. "... the earth from the very beginning of its existence as a gaseous and later molten piece of matter was torn away from the young sun by some passing star, down to the very end, when it will be melted again in the last desperate explosion of its dying parent." The crust of the earth solidified 1.6 thousand million (1.6×10^9) years ago, is a recent estimate. Scientific researches of the earth's interior indicate that most of its body is still in a molten state (97%). It has a temperature between 1200°C to 1800°C (melting point of rocks) at a depth of only 50 kms. Vedic views about the creation of the earth, its shape and its interior are:

कतरा पूर्वा कतरा परायोः कथा जाते कवयः को विवेद ।
विश्वंत्मना विभृतो यद्ध नाम विवर्तते अहनी चक्रियेव ।:

Rigveda, I, 185, 1.

i.e. which of these (the sun and the earth) is elder? Which is later? How were they born? Who knoweth it, ye sages? However, *Yajurveda*, XXXVII, 4, indicates that the earth was born first in the cosmic creation.

देव्यो वभ्रयो भूतस्य प्रथमजा ।

The interior of the earth is extremely hot. The *Satapatha Brahmana*, XIV, 9, 4, 21 mentions this fact. in Vedic literature contains the information that the earth is round in shape (*Satapatha Brahmana* VII, 1, 1, 37).

अग्निगर्भा पृथिवी ।
परिमण्डल उ वा अयं (पृथिवी) लोकः ।

The earth is a planet and is the largest of the four inner planets. It rotates round its axis once a day and revolves round the sun in 365°256 days. This period is known as a sidereal year. Axis of rotation of the earth is inclined to the plane of its orbit by an angle of 66·5°. The earth turns towards the sun periodically in its northern and southern hemispheres, and this fact causes the change of reasons. The moon rotates round the earth, causing day and night.

The descent of man on the earth

After discussing the creation of the universe and the creation of the earth, it would be in the fitness of things if we discuss the creation of man. There are two schools of thought. One subscribed to the view that man grew and evolved slowly from the monkey. The other is that man grew from man and the existence of man is original.

Vedas consider all men to have descended from the 'First Man' the Vivasvat's son Manu or Yama Vaivasvata, who with his twin sister Yami produced the human race. At some other places, Agni is said to have begotten Angirases, the semi-divine ancestors of the priestly families, from whom the human race originated.

The history of mankind can be divided into three ages viz. (1) the Age of stone, (2) the Age of Bronze, and (3) the Age of Iron. Stone Age can be further divided into three periods—the Palaeolithic, Mesolithic and Neolithic *ie* the Old, Middle and New Stone Ages. The Palaeolithic of the archaeologists corresponds to the Pleiztocene of the geologists.

The first discovery of palaeolithic tool in India took place in AD 1863 at Pallavaram near Madras; it was by Robert Bruce Foote of the Geological Survey of India. During the next seventy years or so, palaeoliths were discovered, in large numbers almost all over India except on the Indo Gangetic plains), but there was no serious effort to place them against the geological context.

Scientific clues have established that the earth was formed two billion years ago. It remained lifeless for 500,000,000 years. On earth, life began 1,500,000,000 years ago. Chemicals including minute quantities of potassium, sodium, iron, copper, chlorine, bromine and others, somehow combined with protein to form a new substance known as *Protoplasm* It is thought to be the first material on earth to show the properties of life. Protoplasm (sometimes called living matter) is the key material out of which the bodies of all plants and animals are made. Under one set of conditions protoplasm acted alive i.e. it secured nourishment and oxygen from its physical environment but under another set of conditions it became dead i.e. reverted to its ingredients. Protoplasm organized into tiny units is known as cells. Each cell constituted a little animal called *protozoon* and the whole group as *protozoa*. The next major step on the road leading from protozoa to man seems to have been taken when offspring cells adhered to their parent instead of severing all ties and going free. This state of evolution in which the whole mass of the cells remained together, is called *colonialism*, Colonialism lead to the evolution of *metazoa*, multicellular organisms where some cells became specialized only for breathing, others for locomotion and so on. Each cluster of cells, carrying a biological activity got arranged into a tissue and then into an organ. Metazoa, no one of which possessed a real backbone, are now classed as invertebrates.

Furthermore, there are clear indications that by a series of evolutionary steps the first vertebrates descended from invertebrate ancestors. Then bony fishes made their appearance in water. From them was the evolution of air-breathing and walking fishes. They developed into *amphibians* e. g. frog. They began life in water but matured into land dwellers. Then appeared reptiles and finally mammals. The following timetable gives the geological record of animal evolution:

THE EVOLUTIONARY TIMETABLE

Era	Beginning Date (Approximate)	Major Animal Group
Azoic	2,000,000,000 BC	None
Archeozoic (ancient life)	1,500,000,000 BC	Protozoa
Proterozoic (former life)	1,000,000,000 BC	Metazoan Invertebrates
Paleozoic (old life)	500,000,000 BC	Fishes and Amphibians
Mesozic (middle life)	200,000,000 BC	Reptiles
Cenozoic (recent life)	70,000,000 BC	Mammals

Primate evolution can be put in the form of following chart:

CHART OF PRIMATE EVOLUTION

Era	Period	Epoch	Beginning date (approximate)	Main animal Group
Cenozoic	Tertiary	Paleocene	70,000,000 BC	Insectivora
		Eocene	60,000,000 BC	Lemurs Tarsiers
		Oligocene	40,000,000 BC	Monkeys
		Miocene	30,000,000 BC	Apes
		Pleiocene	13,000,000 BC	Man-apes
		Pleistocene	1,000,000 BC	Extinct Hominids
	Quaternary	Holocene	50,000 BC	Homo sapiens

From all that has been written on the subject no one knows exactly how and when the immediate forbears of man acquired their most distinctive body traits. Most often it is assumed that the process was somehow connected with assumption of upright posture on solid earth. Despite doubts raised by the discovery of the South African man-apes, the process can be most meaningfully discussed if it is tentatively assumed to have taken place while large, arboreal, basically quadrupedal primates were changing to terrestrial bipeds.

Anthropologists and Geologists have attempted to trace the records of early man. One school of anthropologists holds that traces of man's handiwork are first seen in tertiary deposits and recent evidence supports this view. Till 1975, various anthropologists have assigned to the earliest signs of man, the period one to ten million BC.

Some Recent Clues: Recently (May 1976), information based on archaeological excavations about early man, has been given by a research team led by Dr. S.R.K. Chopra of Department of Anthropology, Punjab University, India. According to them, early men-like apes (Dryopithecines) and man-like forms (Ramapithecines) lived in India fourteen million years ago. Fossils of a small rodent-like creature known as insectivora, which the palaeontologists believe gave rise to the earliest primates, have recently been unearthed from a site about one km. to the west of the well-known Hari temple in Haritalyanagar Village, Bilaspur District, Himachal Pradesh, India. They found a dozen specimens of insectivores consisting of complete skulls, mandibles and fragmentary skeletal parts. These are the first findings of such primitive mammals from the Nagri beds of the Miocene age, extending approximately fifteen to million twenty million years in the Sivaliks.

Dr. Chopra's team is actively engaged in exploring sites for exacavating remains of the early man and his ancestors in the Sivaliks, particularly in the Bilaspur district. The sites around Barotiwala and Nalagarh of Solan district and between Mehad in Una district and Daulatpur in Kangra district of Himachal Pradesh have yielded hundreds of stone tools representing various stages of man's development.

The site discovered by Mr. Baldev Singh in Solan Valley, about twenty km. from Una, is significant. A sequence of four non-paired terraces could be recognized from where stone tools consisting of choppers and flakes have been collected. Evidence reveals that these terraces were once inhabited by prehistoric man.

Meanwhile, Punjab University has utilized all fossil evidence available in the Sivalik hills to reconstruct life-size models representing the ape-man. Not only are bodily dimensions and evolutionary trend reconstructed, but also the ecological niche against which the early man developed and lived millions of years ago have been worked out. According to Dr. Chopra, from the evidence gathered a gradual picture was emerging on the series of events that led to the emergence of man in India. But to reconstruct these models was not an easy task as they still did not have many clues to the profile of the ape man of the Sivalik hills, much less a complete skeleton of a homonid, which has not been discovered in any part of the world yet. The only material available, in the Sivaliks comprised of the fossil remains of early man like apes (Dryopithecines) and man-like forms (Ramapithecus), which are belived to have lived fourteen million years ago.

It was in 1968 that two members of a Punjab University field team, Makhmir Sidhu and Samvit Kaul were able to recover a fragment of a fossil lower jaw from a peasant, who had found it while digging his field in Haritalyanagar area. Later the researchers were able to obtain two more fragments of the same jaw from the peasant. Excavation was immediately started at the site. Research led to the conclusion that this unique find belonged to the largest ever known ape from the Sivaliks. The jaw has nearly a complete array of teeth with only the front two incisors and a left premolar missing. Judging from the dental formation and mode of tooth wear, experts feel that the giant ape allowed a sideways motion of the jaw thus providing increased power of grinding and a more efficient way of eating. This was unlike modern apes, where interlocking cannines limited masticatory action only to up and down movements. Dr. Chopra says that if the dimension of the jaw is any indication of the body size, the giant ape might have weighed and attained a size not much larger than the present gorilla. The present gorilla weighs about 181 kg. and when standing on its hind feet, is approximately 1.8 m. tall.

The earliest signs of man are flints and other hard stones. The oldest stone tools, named Palaeoliths are difficult to distinguish from natural products, flints chipped accidentally by the action of water or movements in the earth. Ignoring the doubtful finds, we can divide the Stone Age into two major parts-Palaeolithic and Neolithic. Palaeolithic men chipped their implements; they hunted wild animals, but did not tame them; they did not cultivate the soil.

Neolithic men learnt the arts of domesticating animals and plants, cultivating the soil, making fire for roasting their food and for their safety. So they were able to have a more secure supply of food. They settled down in small communities.

Early Civilizations

Our own species, *Homo sapiens* appeared perhaps some fifty thousand years ago. The first men had almost to learn everything. The primitive men began roaming about on earth, depending on plants and animals for their existence. They had a natural curiosity for knowing the things around them. They started examining their surroundings in order to discover which types they could use for food, shelter and clothing; which plants they could use for curing diseases and which animals they could use for work. They settled down in small communities and made their dwellings. The health and disease of their own body, and birth, growth and death of their chlidren occupied their attention. In due course, the primitive men accumulated a fair amount of knowledge about living creatures and plants, but this knowledge was often unscientific.

The very early history of civilization is largly unknown, but at present it appears that in the earliest times there were at least three contemporary (5000 BC-3200 BC) civilizations all of which have begun in the basins of great rivers:

1. The Nile Valley — Egyptian
2. The Euphrates and the Tigris — Sumerian which transmitted to the Babylonians in Mesopotamia and thence to the Assyrians.
3. The Indus Valley — Indian, about which little was known to the world till Nineteenth century; Archaeological excavations (AD 1921) at Mohenjo-daro and Harappa, revealed the existence of the ruins of very ancient (3250 BC) and well-planned cities.

Little less old is the civilization of China, which appeared in the valley of the river Yangtze Kiang. There are legends ranging back to some time as 2700 BC, but historical records establish the existence of this civilization only about 2000 BC. A further, separate civilization arose in central and south America.

3

Science in India

PRE-SCIENCE

The first man, believed to have appeared a few million years ago, had almost to learn everything. They roamed about on earth depending on plants and animals for their existence. They lived in caves and trees. For safety, they started living in groups. Group-life-psychology and the discovery of fire ensured them protection from wild animals. They began to build huts. Their dependance on plants and animals, and their natural curiosity for knowing the things around them, led them to examine various plants and animals. This they did to discover the types that would supply them with food, shelter, clothing, cures for ailments and tools for work. Such cultures came into existence in many different ages, in different parts of the world. Those which developed (about 5000-3000 BC) into earliest civilizations, in the basins of great rivers—the Nile, Euphrates, the Tigris, and the Indus, are respectively the Egyptian, the Sumerian (which transmitted into Babylonian in Mesopotamia and thence to Assynian), and the Indian/Indus/Sindhu/Hindu/Aryan.

Knowledge developed further with the discovery of the means of expression and communication, firstly in the form of pictorial writings and later in the form of different languages.

SCIENCE

The word 'SCIENCE' is derived from the Latin (Roman word 'Scientia' or 'Scire' which means knowledge. This meaning was attached to different words in different parts of the world—wherever the pursuit of knowledge became a human activity. In Bharat (India), the word 'Veda' meant knowledge. The *Vedas* (most important ancient Indian texts), encapsulate an incredibly rich fund of almost all aspects of knowledge. Science, in its widest sense, is a systematic method of describing and controlling the material world. Science may be regarded as a minimal problem consisting of the fullest possible presentation of facts with the least possible expenditure of thought. It is the systematised store of human knowledge about nature. Thus the history of science must include history of development of all aspects of knowledge. But customarily science is used in a narrow sense to denote an ordered knowledge based on observations and experiments, excluding such humanistic studies as language, sociology, economics and political history.

Science as something existing and complete is the most objective thing known to man. But science in the making, science as an end to be pursued, is as subjective and psychologically conditioned as any other branch of human endeavour—so much so that the question, What is the purpose and meaning of science, receives quite different answers at different times and from different sorts of people. It is, of course, universally agreed that science has to establish connections between the facts of experience, of such a kind that we can predict further occurences from those already experienced. Indeed, according to the opinion of many positivists, the completest possible accomplishment of this task is the only end of science.

Science crystallized from several different sources and in different places. It receives many more influences from the general mental atmosphere of its time. So long as science cannot give autonomy to its criteria not only of what is true but of what is interesting, it is fatally hampered. Science has two main objects—to enable men to *do* and to *know*. The desire to know, purely for the sake of knowledge motivates the men of science. The knowledge so gained may or may not be adapted for satisfying the material needs of society. Further, the wish to *satisfy* material needs may lead to researches which in turn contribute to pure knowledge. In the beginning, all economy had in immediate view the satisfaction of simple bodily wants. Economy of communication and of apprenhension is the very essence of science.

Every *citizen* is directly and vitally concerned with science. Pure science has moulded his philosophy of life and applied science has determined almost the whole of his material surroundings, his chances of life or death, poverty or affluence, freedom or slavery. Science gives an intelligible picture of what man perceives by senses in so far as it can be expressed in terms of numbers, ratios, sizes, shapes, weights and motions and all the qualities and units derived from these. Thus it sums up in a rational way a great part of man's relation with the external world. It helps in moulding the external world to many of our wills. But will is no part of science, and science cannot tell man what he should do. He has to decide what he wishes to do, what is good or desirable; then science will tell him how to do it and what will happen when he has done it, in so far as this is within its scope. It cannot teach morals and so cannot improve the ethical side of man's nature. The ethical and moral life has throughout the ages, been included in the province of *Dharma* (an extension of religion). Science has helped religion by removing many superstitions bedevilling it.

Science prevents suffering, cures diseases, lengthens life, wings us through space, transports us on land or water, builds our homes, makes our clothing, preserves our food, purifies our water, increases our pleasure, deepens our understanding, warms us in winter, cools us in summer, and helps us day and night in many other different ways. It has profoundly influenced our life. Those who remember that scientific laws are summaries of observations and not legal enactments will have no difficulty in discovering the phenomena to which these can safely be applied. Science can also increase the powers of tyranny over man and abuse of nature to unimaginable limits. It has already offered man the most diabolical power to destory his fellows. The discovery of atom bombs and many poisonous substances have equipped him with lethal weapons. These discoveries can be used for constructive purposes also. The atom bombs were used in World war II and resulted in heavy losses to life and property. At present many nations have made stocks of atomic weapons. In view of the existent human rivalaries, these have posed a danger to the entire mankind. Due to this threat, the ethical slogans of disarmament and nonalignment are gaining strength day by day, at the international level. The need of the hour is to follow ethical, moral and scientific discipline *ie.* proper admixture of science and *Dharma* (which includes religion).

SCIENCE IN ANCIENT INDIA

Though science donotes all type of knowledge but customarily it denotes knowledge based on observations and experiments. So, herein science in India will be discussed in this sense of the word.

Very little was known of the ancient Indian science before the eighteenth century. The English historians were of the view that the Hindus had ever been in the same abject condition in which they found them. Most of the Indians at that time were oblivious of their glorious past except in some vague terms. The works of early oriental scholars like William Jones, Princep, Bohtlink, Max Müller, Prof. Goldstucker, Prof. J.D. Bernal, Prof. Wilson, Fergusson and archaleogical exploration started since 1861, brought home to the educated Indian a vivid picture of the past glory and greatness of science in ancient India. More light on this has been shed by many scholars of the calibre of Prof. Brajendernath Seal, Sir P.C. Ray, A.K. Biswas, Dr. Satya Prakash, Shankarachrya Bharati Krsna, Dr. D.D. Mehta and Prof. O.P. Jaggi. In 1964, the Government of India established a 'National Commission for the Compilation of History of Science in India.' This was composed of a number of scientists and historians. With their help, the Indian National Science Academy, New Delhi, was able to publish in 1971, a comprehensive work—*A Concise History of Science in India.*

The study of science is a human pursuit which is thoroughly international in essence and import. Though it has become a tradition to believe that science and other strands of human culture have their orign in the eastern outposts of Greek Confederation, yet to those, who have even a little insight into the vital and prominent role played by the Aryan scientists, the truth of Manu about the cultural heritage of Bharat (India) needs no emphasis. Manu proclaimed:

एतद्देप्रशसूतस्य सकाशात् अग्रजन्मन : ।
स्व स्वं चरित्रं शिक्षेरेन् पृथिव्यां सर्वमानवा: ।।

Manusmiriti, II, 20.

i.e. 'From a Brahmana, born in this country, let all men on earth learn their several usages.'

The great sage Yajnyavalka of the time of King Janak declared:

विज्ञानमानन्दम् वृह्मा ।।

i.e. 'the real purpose of life lies in the scientitfic investigation of this universe.'

The *Narada Samhita* makes us familiar with the eighteen earliest scholars of India:

ब्रह्मचार्यो घसिण्टोइत्रिर्भनु: पौलस्त्यलोमशौ
मरीचिरं गिरा-व्यासो नारद; शौनको भृगु : ।
च्यवनो यवनो गर्ग: कश्यपश्च पराशर :
अष्टादशैते गंभीरा: ज्योति: शास्त्र प्रवर्तका : ।।

1.	ब्रह्मा	(*Brahma*)	10.	व्यास	(*Vyasas*)
2.	सूर्य	(*Surya*)	11.	नारद	(*Narada*)
3.	वसिष्ठ	(*Vasishtha*)	12.	शौनक	(*Shaunaka*)
4.	अत्रि	(*Atri*)	13.	भृगु	(*Bhrigu*)
5.	मनु	(*Manu*)	14.	च्यवन	(*Chyavana*)
6.	पौलस्त्य	(*Paulastya*)	15.	यवन	(*Yavana*)
7.	लोमश	(*Lomasha*)	16.	गर्ग	(*Garga*)
8.	मरिचि	(*Marichi*)	17.	कश्यप	(*Kashyapa*)
9.	अङ्गिरा	(*Angira*)	18.	पराशर	(*Parashara*)

Aatharvan (also called as Angira or Atharvangiras) was the first discoverer of fire. This fact has been recognised by western scholar Griffith. The people who experimented and analyzed fire were named 'Angiras' after Angira. This ultimately became a caste. There are numerous references to Angira in *Rigveda*, *Atharvaveda* and *Yajurveda* e.g.

> पुरीष्योऽसि विश्वम्भराऽ अथर्वा त्वा प्रथमो निरमन्थदग्ने ।
> त्वामग्ने पुष्करादध्यथर्वा निरमन्थत । मूर्ध्नो विश्वस्य वाघतः ॥

At a later stage, the following scientists were born in India and contributed a lot to different branches of science.

Medical Men: Dhanvantri, Bharadwaja, Atreya, Jivika, Patanjali, Charaka, Susruta, Vagbhata, Umasavati, Madhavakar, Vrnda, Dridhabala, Bhave Misra, Anandarayamakhi, Solihotra and Maheswari.

Astronomers and Mathematicians: Baudhayana, Garga, Lagadha, Medhatithi, aryabhata, Srisena, Varahamihira, Brahmagupta and S. Ramanujan.

Philosopher Scientist: Kanada, Kapila and Gotama Aksapada

Ship-Building Authority: Bhoja

Ancient Agriculturist: Khana

Scholars view on Science in India

Let us consider the views of some internationally well known scholers, about science in India.

Max Müller said in '*India, what can it Teach us,*' "If I were asked under what sky the human mind has most fully developed some of its choicest gifts, has most deeply pondered on the greatest problems of life and has found solutions of some of them which deserve the attention even of those who have studied Plato and Kant, I should point to India."

Lenin* not only asked the Russian intellectuals to study the ancient Indian heritage but in his enthusiasm, he asked them to go to the Russian working class and explain it to them. In his conversation with S.F. oldenburg, Lenin said, "Well, here is your subject. It seems far away. Yet it is close. Go to the masses, to the workers and tell them about the history of India......and see how they will respond to it. And you yourself.. ...draw inspiration from it for fresh research, work and study of great scientific importance."

Laplace said, "How grateful we should be to the Hindus who discovered this great decimal system that did not occur to the minds of such mighty methematicians as Archimedes and Apollonius"

Prof. Albert Einstein, who is regarded as the greatest scientist of the twentieth century once said, "We owe a lot to Indians, who taught us how to count, without which no worthwhile scientific discovery could have been made."

According to Goldstucker, "The most scientific grammer that the world has ever produced with its alphabet based on thorougly phonetic principles was composed in India."

Prof. Mecdonell's tribute is significant: "We Europeans......2500 years later and in a scientific age, still employ an alphabet which is not only inadequate to represent all the sounds of our language, but even preserves the random order in which vowels and consonants are jumbled up as they were in the Greek adaptation of the primitive arrangement of 3000 years ago." He further said, "In science too, the debt of Europe to India has been considerable. There is, in the first place, the great fact that the Indians invented the numerical figures, used all over the world. The influence which the decimal system of reckoning, dependent on those figures has had, not only

---

*Modern Ideological struggle for the Ancient Philosophical Heritage of India, N.P. Anikeer, p. 61.

16352

on mathematics but on the progress of civilization in general, can hardly be overestimated. During the eighth and ninth centuries, the Indians became the teachers, in arithmatic and algebra, of the Arabs and through them of the nations of the West."

British scientist-cum-historian, Prof. J.D. Bernal writes in '*Science in History*.' There was also, and this is of greatest importance for the whole world, a new development of science, particularly mathematics and astronomy associated with the names of the two, Aryabhatta and Varahamihira in the fifth century and with Brahmagupta in the seventh......A decisive new development was made there about this time. The perfection of a number system with place value notation and a zero......The Arabs also incorporated the work of a series of Indian mathematicians on the means of dealing with unknown quantities which we call algebra."

Prof. John Barden of the University of Illinois, winner of 1965 and 1972 Nobel Prizes, while (Jan. 9, 1977) receiving Delhi University's Hon. D.Sc. said, "The world has a lot to learn from India and its sages, espccially since fossil fuels, responsible for the western world's recent prosperity, were likely to be exhausted by the end of the century. Prosperous Nations will have to learn to change their life-styles as a result."

These quotations amply corroborate the superimacy of the Indian thought (*Bhartiya Darshan*). In fact, there is a dire need for a systematic and scientific study of all ancient Indian texts.

Indians enlightened the Greeks, the Europeans

As early as when the Greeks had just begun to develop philosophical thinking, history has on record the details of discussion between the Greek King Milind and the Buddhist philosopher Nagasen to whom the king went for enlightenment. The fact that the king finally took to Buddhism confirms the indisputable fact that knowledge was not flowing from Greece to India. Indian thought had clearly begun to enlighten the western thinkers centuries before the dawn of the Christian era. Long before the invasion of Alexander, from 500 BC onwards, exchange of knowledge was already established between the Hindus and the Greeks. This was a period when Kuru ruled over Kambhoj, present Afghanistan and Iran.

It is for the west to answer the mystery as to why king Clement of Alexandria called the Greek philosopher and mathematician Pythagoras (570-497 BC) as 'the pupil of a Brahmin'? Pythagoras was well known to the world for his ascetic life and vegetarianism which he enthusiastically preached in the West. The theorem which goes in his name, was known in India, at least two centuries before his birth. The following statement is found in several places in *Satapatha Brahmana* and *Baudhayana Sulabasutra:* 'The transverse chord of a rectangle produces, by the construction of a square on itself, what the length and breadth produce seperately.' Every Brahmin was supposed to know the theorem as a part of *Yajana* for making the *Vedi*. There is every chance that Pythagoras might have learnt this theorem from Indians. Any way, he can't be credited for the originality of the theorem.

It is again for the west to answer why physicians were called to Persia about 200 AD to give anesthesia for a painless operation? Why at the time when Indians were supposed to be just learning from Greeks, the great works on chemistry of Nagarjuna and many others were enthusiastically translated in Chinese and other foreign languages? The Greeks who came to India before the Christian era have recorded that medical science in India was highly developed and the Indian doctors were praised for their specialised knowledge of treatment of poisons etc. When *Ayurveda* was translated into the Latin Language, the translatar could not translate the Sanskrit terms '*Arugna phuphus murmur*' meaning the instrument of Stethescope which was used by physicians in India. He translated it in Latin as, "Healthy Vascicular Murmur" retaining the original Sanskrit word '*murmur*' which exists in English language even today in its original form.

Also *Vishnu Purana* says that at the time of Sambh (i.e. at the time of *Mahabharata*), the Brahmins of regions outside India and particularly the whole of central and West Asia knew the four *Vedas*, in a slightly distorted form. Since the originals were available in India, so migration must have taken place from India to the West as against the general theory of the Aryans branching off to India, Europe and Middle East from somewhere in the North.

If all thinking in India begins after Christ when Greek knowledge is supposed to have reached India, how is one to explain the composition of the *Gita*, which is accepted, even by the western scholars, to be not later than fourth century BC? It would be relevant to quote Marxist philosopher Bani Despande in '*The Universe of Vedanta*' as saying, "It is my firm opinion that *Gita*, as the quintessence of the ancient Vedanta philosophy, is based on the doctrine of dialectics which was unknown to the west untill Marx could explain it in the nineteenth century and its higher development is still unknown in the twentieth century.' Also if Samkhya and Yoga were developed after Christ, by Kapila Muni, on the basis of knowledge derived from the Greek thinkers, how could Krishna say. in the *Gita* that he was the incarnation of Kapila Muni: (सिद्धाना कपिलो मुनि : ।, *Gita*—10-26; *Shanti*—340-60). This exposes the rediculous western line of thinking that Kapila Muni lived after Pythagoras.

Jean Filliozat, the eminent French Indologist said, "the greatest historians of science have not always escaped from the inconvenience of knowing only one side of the matter. Paul Tannery, so famous for his studies on ancient mathematics, is an example. We know that the trigonometric-sine is not mentioned by Greek mathamaticians and astronomers; that it was used in India from Gupta period onwards, that the Surya-Siddhanta gives a table of sines, that the Arab astronomers knew them from their Indian contacts and passed them on to Europe in the twelfth century, when the work of Al-Battni (AD 858-929) known as Albategnius in medieval Europe, was translated into Latin......But Paul Tannery, persuaded that the Indians could not have made any mathematical inventions, preferred to assume that the Indians knew sines was sufficient proof that they must have heard about them from the Greeks......If this is the way, we are to argue, there was never any science other than Greek science, and the question whether science has any origin other than Greek 'miracle' is solved in advance."

Sebokht, a Syrian Priest-Astronomer of the seventh century AD wrote, 'I shall now speak of the knowledge of the Hindus, of their subtle discoveries in the science of astronomy—discoveries even more ingenious than those of Greeks and Babylonians, of their method of calculation which no word can praise strongly enough, I mean the system using nine symbols. If these things were known to the people who think that they alone have mastered the sciences because they speak Greek, they would perhaps be convinced though a little late in the day that other folk, not only Greeks, but men of different tongue know something as well as they.' This shall suffice to answer critics like Paul Tannery.

The famous Chinese scholar Fa-hien who came to India in search of knowledge, spent about ten years in the Gupta empire (AD 401-410). His intensive report includes refrences to the great centres of learning, liberal governments and their patronage to education, instances of inter-caste marriages, abundance of hospitals, taxing system based on the richness of the locality, Importance of the Vaisya (merchants) community, and above all effective law and order.

Indian sciences were transmitted to the Arabian countries through translations of the Sanskrit literature into Arabic, or indirectly from Sanskrit to Persian and then to Arabic. It is said that during the eighth century, when Sind was under the actual control of the Caliph Mansur (753-774), scholars from that part of India went to Baghdad and they took with them works of Brahmagupta. These works were translated by Arabian scholars with the help of Sanskrit *Pundits*. It is through them the Arbians first became acquainted with Indian mathematics and astronomy. This knowledge was further transmitted through Arabians to the nations of the West.

MATHEMATIC AND ASTRONOMY IN INDIA

The history of the development of mathematics and astronomy in India is as old as the civilization (Indian civilization has now been realized as the oldest civilization) of its people. The growth of mathmatical and astronomical sciences is the most glorious chapter of Indian science. Now it is an internationally accepted fact that the numerals 1 to 9, zero '0' (शून्य) and decimal place value notation are unique Indian contributions to the world of science.

The development of mathematics and astronomy begins with the rudiments of metrology, computations and the number system used in India, in prehistoric times. Some fragmentary evidence has survived to this day.

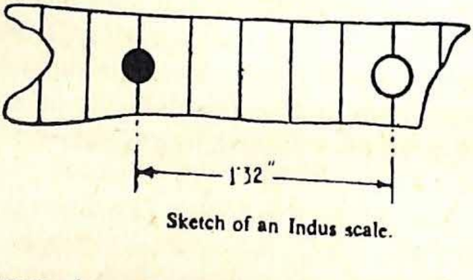
The sacred literature of the Vedic Hindus—the *Samhitas*, the *Kalpasutras* and the *Vedangas*—contain enough material. The *Sulbasutras* which form a part of the *Kalpasutras* contain varied informations about enumeration, arithmetical operations, fractions, properties of rectilinear figures, the so-called Pythagoras theorem, surds, irrational numbers, quadratic and indeterminate equations etc. The *Brahmanas* and some *Sutras* contain interesting material concerning progressive series, permutations and combinations.

Of the various religious sects that attained prominence in the closing phase of the Vedic period, the Jainas deserve special notice for their interest in the cultivation of mathematics. Their canonical literature lays great emphasis on various topics such as number reckoning, fundamental operations, geometry, mensuration, fractions, equations, permutations and combinations. Their canonical texts include *ganitanuyoga* (principles of mathematics), *samkhyana* (arithmetic) and *jyotisa* (astronomy).

In 1921 archaeological excavations conducted at the sites of Mohenjo-daro in Sindh and Harappa in Punjab revealed a developed civilization—The Indus Valley civilization. It brought to light developed cities in seven different layers of buildings which has been assigned the period 3225 BC to 2750 BC.

It is reasonable to believe that the builders of the Indus civilization developed a good degree of skill in their measuring and computational techniques. Without these it is difficult to comprehend their town-planning and architectural proficiencies and various other aspects of their civilization. As to metrology, we have the evidence of seals with pictographic inscriptions and numerous stone weights unearthed at Mohenjo-daro and Harappa. Some of the pictographic inscriptions have not yet been deciphered. Most weights appear to be fractions or multiples of the *uncia* (one *uncia*=27·2 gm.).

An interesting specimen of the Indus scale has come down to us among the finds from Mohenjo-daro in the form of the fragment of scale measuring 6·62 cm. in length by 0·62 cm.



Sketch of an Indus scale.

The scale shows nine parallel lines cut with a fine saw. One of these lines is marked by a fine circle and the sixth line from it by a dot. The measurement of these five intervals shows 1·32 inches. This can be called the 'Indus inch.'

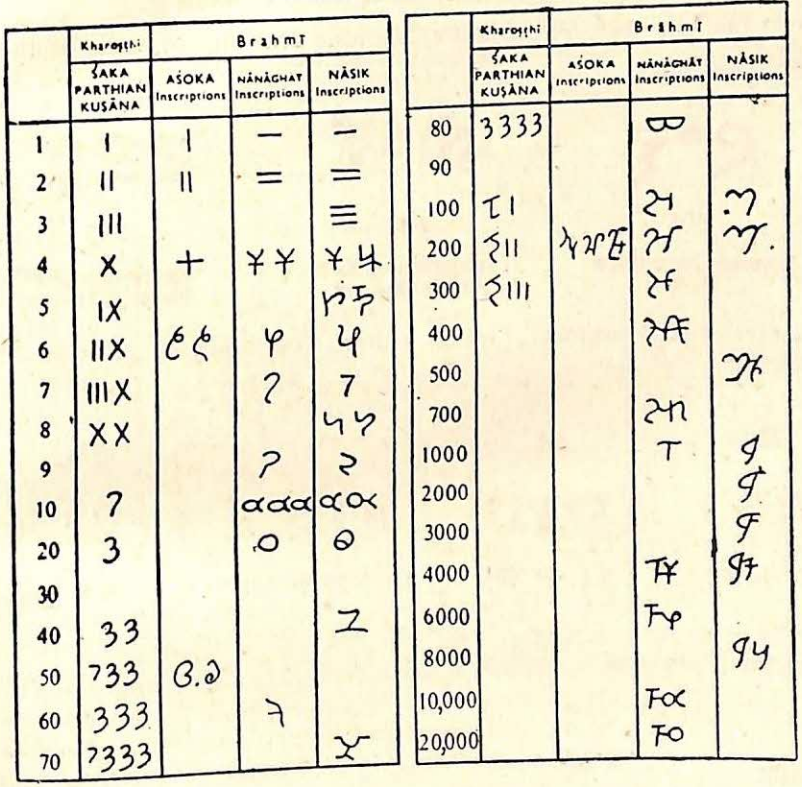
Indus seals and inscriptions (archaeological excavations, 1921) as found in Mohenjo-daro, show that the numbers were represented by vertical strokes arranged side by side or in lateral groups.

1 = 111 IIII III II
(1 2 3 4 5)

No evidence have survived so as to say how far ancient Indians went in representing higher numbers. Some of these strokes survived in the *Kharosthi* and *Brahmi* numerals. The epigraphic records of numeral notations in India, of both non-place and place value are summarized in Table I and Table II.

TABLE I

Numerals without place-value



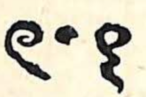
	Kharoṣṭhī	Brahmī		
	ŚAKA PARTHIAN KUṢĀNA	AŚOKA Inscriptions	NĀNĀGHAT Inscriptions	NĀSIK Inscriptions
1	I	I	—	—
2	II	II	=	=
3	III			≡
4	X	+		
5	IX			
6	IIX			
7	IIIX			7
8	XX			
9				
10	7			
20	3			
30				
40	33			
50	733			
60	333			
70	7333			
80	3333			
90				
100				
200				
300				
400				
500				
700				
1000			T	
2000				
3000				
4000				
6000				
8000				
10,000				
20,000				

Table II shows numeral forms used in decimal place-value system and found in stone as well as in grant-plate inscriptions.

A circular symbol for zero appears in the Gwalior inscription (as shown in column 4 of Table II pertaining to the reign of Bhojadeva in which the verses were numbered from 1 to 26 in decimal figures. *The Gwalior inscriptions provide the earliest palaeographic record so far known in India of the use of zero in a decimal place-value system.*

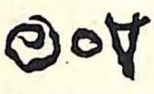
Still earlier dates can be located from the Hindu colonies of south-east Asia. Decimal place-value numerals with a point (*sunya-bindu*) as well as a circular symbol for zero have been discovered in the seventh century inscriptions—two at Palembang in Sumatra and one in Banka. These give the Saka dates 605, 606 and 608 in figures. Still another old Srivijaya inscription found in Sambor.

gives the Saka date 605 in figures. Sample drawings of some of these figures are:



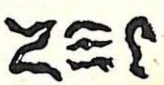
605

Khmère inscription of Sambór



608

Inscription of Kota Kapur (Banka)

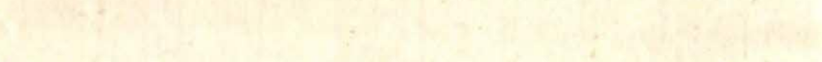


735

Inscription of PO Nagar (Champa)

Intermediate numbers were written on additive principle as follows:

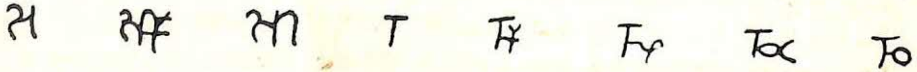
22 74 122 274



(2 + 20) (4 + 70) (2 + 20 + 100) (4 + 70 + 200)

Nānāghat

100 400 700 1000 4000 6000 10,000 20,000



Nāsik

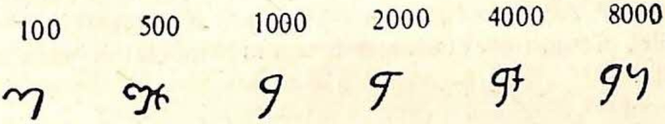
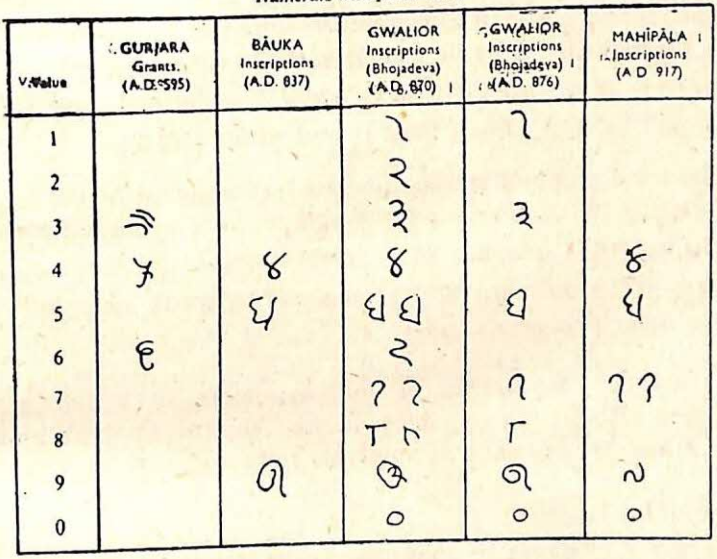


TABLE II

Numerals with place-value


Value
GURJARA Grants. (A.D. c595)
BÂUKA Inscriptions (A.D. 837)
GWALIOR Inscriptions (Bhojadeva) (A.D. 870)
GWALIOR Inscriptions (Bhojadeva) (A.D. 876)
MAHÎPÂLA Inscriptions (A D 917)
1
2
3
4
5
6
7
8
9
0

The word-numerals and their use in a decimal place-value arrangement represent another unique development in India.

Numeral	*Meaning*	*Words*
0	Emptiness, void etc.	*Kha, akasa, ambora, sunya*
1	Earth, Moon	*kriti, dhara, prithivi, indu, candra*
2		*vama, asvin, dasra, aksi*
3		*rama, guna, agni*
4		*veda, samundra*

The Vedic Hindus had the proficiency in developing scientific vocabulary of the following number system (sources; *Yajurveda Samhita, Taittirya Samhita, Pancavimsa Brahmana*) in which the principles of addition, subtraction and multiplication were conveniently used:

(1) The first nine digits, e.g. *eka*, *dvi*, *tri*, *cature*, *panca*, *sat*, *sapta*, *asta*, *nava* (i.e. एक, दो, तीन, चार, पाँच, छः, सात, आठ, नौ)

(2) 'The zero '0' (शून्य=*Sunya*) and the place value notation (the decimal system).

(3) The second group of nine numbers obtained by multiplying each of the digits in (1) by 10, e.g. *dasa* (दस), *vimsati* (बीस), *trimsat* (तीस), *catvaimsat* (चालीस), *pancasit* (पचास), *sasti* (साठ), *saptati* (सतर), *asiti* (अस्सी), and *navati* (नब्बे)

(4) The third group of eleven numbers beginning with 100, e.g. *sata* (सैकड़ा=100), *sahasra* (सहस्त्र=हजार 10^3), *ayuta* (दस हजार), *niyuta* (लाख), *prayuta* (दस लाख), *arbuda* (करोड़), *nyarbuda* (दस करोड़), *samudra* (अरब), *madhya* (दस अरब), *anta* (खरब) and *parardha* (दस खरब=10^{12}).

The name of Medhatithi, a mathematician of Vedic times, is associated with numerous verses in the *Rig*, the *Atharva* and the *Yajur Vedas*. He enumerated numerals upto 10^{12}.

Bakhshali Manuscript

The earliest evidence of the use of the place value notation has been formed in Bakhshali Manuscript (BM). This was unearthed by a farmer in May, 1881, in a small village called Bakhshali near Peshawar (now in Pakistan). Written on birch barks in *Sarada* script, the manuscript has survived in about 70 leaves, some of them in mere scraps. It was presented to the Bedleian Library, Oxford by Dr. A.F.R. Hoernle in 1902. The period* of composition of BM is placed in the range AD 200-400. Zero was represented by a dot in BM An item of great historical importance in BM is the *sutra* (formula) for computing the square-roots of non-square numbers. M.N. Channabasappa, in his research paper published in *IJHS* (vol. 11, No. 2, Nov. 1976), asserted the following correct version of the *sutra*:

अकृते रिलष्टकृत्युनातू शेषच्छेदो द्विसंगुणः ।
तद्वर्गदल संश्लिष्टहृति शुद्धिकृति क्षयः ॥

(*akrte slista krthyunat sesa cchedo dvisangunah*
tadverga dala samslistha hrti suddhi krti ksaya

$$\sqrt{A^2+b} -- \frac{A^2+b}{A}, A+\frac{b}{A}, A+\frac{b}{2A}, \left(\frac{b}{2A}\right)^2, \tfrac{1}{2}\left(\frac{b}{2A}\right)^2.$$

$$\left(\frac{b}{2A}\right)^2 \Big/ 2\left(A+\frac{b}{2A}\right) A+\frac{b}{2A} - \left(\frac{b}{2A}\right)^2 \Big/ 2\left(A+\frac{b}{2A}\right)$$

i.e. $\sqrt{Q} \equiv \sqrt{A^2+b} = A+\frac{b}{2A} - \left(\frac{b}{2A}\right)^2 \Big/ 2\left(A+\frac{b}{2A}\right)$

This formula oocurs in connection with an algebraic problem in BM It was an independent Indian discovery. It is better than Heron's formula:

$$\sqrt{Q} = \sqrt{A^2+b} = A + \frac{b}{2A}$$

(The Greek mathematician Heron lived in the second half of the first century).

Baudhayana Sulba Sutra

A vast literature on ancient mathematics is available in the monumental works ranging from the *Sulba Sutras*** of Baudhayana (800 BC) to the work of the twelfth century mathematician Bhaskaracharya. During the Vedic times, performance of a variety of sacrifices formed a major part of religion. These sacrifices used to be performed at certain pre-calculated times, and in altars of special sizes and shapes. This provided a ground for the growth of astronomy and geometry. Among the literature of *Sulba Sutras* (manuals for the construction of altars), only seven have survived. They are named, after their authors—Baudhayana, Apastamba, Katyayana, Manava, Maitrayana, Varbha and Vadhula. *Baudhayana Sulba Sutra*, is said to have been composed around 800-6000 BC by Baudhayana.

---

*(*i*) B. Datta, *The Bakhshali Mathematics*, BCMS, 21, 2-3, 1929.

(*ii*) Levey, Martin and Petruck, Marvin, Translation of Kushyar Ibn Labban's Principles of Hindu Reckoning, (*Kitab Fi Usul Hisab al Hind*), The University of Wisconsin Press, 1965. pp. 6-7.

(*iii*) *IJHS*, vol. 11, No. 2.

***Sulb* or *Sulv* = to measure; *Sutra* = short rule.

It gives a glimpse of the existent knowledge of geometry. It describes important geometrical propositions necessary for the construction of various altars. It contains a very important result:

> दीर्घचतुरस्रस्याक्ष्णयारज्जुः पार्श्वमणि तर्यङ्गमणि च
> यत्पृथक भूते—कुरुतस्तदुभयं करोति ।
>
> (*dirghacaturasra syaksnayarajjut passvamani tiryanmani ca yatprthagbhute kurutastadubhayam karoti*)

'The diagonal of a rectangle produces areas which its lenth and breadth produce separately', i.e. the square described by a diagonal of a rectangle has an are area equal to the sum of the areas of square as described on its two sides. (see diagram given below)

Baudhayana himself, makes it clear at many places that he was not the first to propound all these methods and mentions his indebtedness to the earlier works and acknowledges their authority, in particular, of *Taittiriya Samhita*, a much earlier composition. *Satapatha Brahmana* contains a statement meaning: 'The transverse chord of a rectangle produces, by the construction of a square on itself, what the length and the breadth produce separately.' Unfortunately, this theorem is usually attributed, without any justification to Pythagoras (540 BC) of Greece.

$3^2 + 4^2 = 5^2$

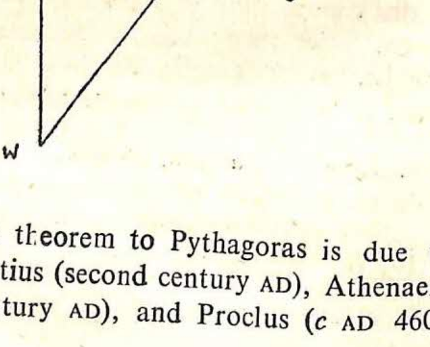
$12^2 + 5^2 = 13^2$

$15^2 + 8^2 = 17^2$

$2^2 + 24^2 = 25^2$

$12^2 + 35^2 = 37^2$

$15_2 + 362 = 39^2$



The tradition attributing the theorem to Pythagoras is due to Cicero (*c* 50 BC), Diogenes Laertius (second century AD), Athenaens (*c* AD 300), Heron (third century AD), and Proclus (*c* AD 460).

Junge* pointed out that the Greek literature of the first five centuries after Pythagoras contained no mention of this or any other important geometrical theorem by the great philosopher Pythagoras. He further pointed uncertainties in the statements of Plutarch and Proclus.

Baudhayana described methods for construction of geometrical figures, combination and transformation of areas, measurements of areas and volumes, squaring the circle and vice-versa, making of similar figures with different areas and a variety of other related problems. The value of square-root of two has been mentioned in the *Sulba Sutra* as 1.4142156.

Ancient Atronomy

Lagadha was the first Indian known to have summarized the available astronomical knowledge (*Ganitajyotisha*) of his time (900 BC). *Jyotisha Vedariga* was composed by Lagadha but its improved text available now, seems to belong to the first century AD. The elliptic path of the earth round the sun was supposed to consist of 27 divisions each equal to 13°, 20′, corresponding to 27 *nakshatras* (constellations). A five-year luni-solar cycle constituted a *yuga*. At the beginning of the *yuga*, the sun and the moon lie at the starting point of the *nakshatra*, *Dhanistha*. There were ordinarily 12 months in a year, each consisting of 30 days. An extra month of 30 days was used to be interpolated during the period of one *yuga*. The year consisted of 6 seasons. A solar-day (sunrise to sunrise) consisted of 30 *muhurtas*, each of 2 *nadikas* (a *nadika* = 10½ *kalas*, 1 *kala* = 124 *kasthas*) and 1 *kastha* = 5 *aksaras*. The time was used to be measured with the help of water-clocks (a vessel with a hole at the bottom and placed on a tub full of water) and sun-clocks. In short, one quinquennial cycle contains 5 sun's revolutions;

67 moon's sidereal revolutions or months;
62 moon's synodie revolutions or months;
1,830 *savana* or civil days;
1,835 sidereal days;
1,800 solar days;
1,860 lunar days or *trithis*.

**A Concise History of Science in India*, INSA, p. 149

In the *Jyotisa* we also find for the first time the rule for determining the length of the day between two solstics (summer solstice = उत्तरायण सूर्य, कर्क संक्रांति; witner solstice दीक्षणायन सूर्य, मकर संक्रांति; Solstice being the point at which the sun is farthest from the equator and appears to pause before receding). The shortest day is given as 12 *muhurtas* at winter solstice and the longest as 18 *muhurtas* at summer solstice. Therefore, the daily increase or decrease of the day length works out to 6/183 *muhurt*.

The concept of *mahayuga* or *chaturyuga* is the central feature of the Indian astronomical *siddhantas*. It is a period at the beginning of which wall planetary bodies are in conjunction. According to Aryabhata, a *mahayuga* is divided into four equal parts or *yugapadas*, each containing 10,80,000 years. In the modern *Surya Siddhanta*, a *mahayuga*, is subdivided into four mundane ages:

The *Krta* or *Satyuga* (golden age)	17,28,000 solar years
The *Tretayuga* (sliver age)	12,96,000 solar years
The *Dwaparayuga* (Brazen or copper age)	8,64,000 solar years
The *Kaliyuga* (iron age)	4,32,000 solar years
Total	43,20,000 solar years

The present *Kaliyuga* started* 'at the midnight between February 17 and 18, 3102 BC at the meridian of Ujjaini. Therefore, *Kali-yuga* was 5082 years old on the midnight between 17 and 18, 1980 AD.

Aryabhata and His Aryabhatiya

On the occasion of fifteenth anniversary of the renowned astronomer Aryabhata, the French astronomer Dr. Roger Billard said, in New Delhi, "I think the history of Indian astronomy to be as a whole the most extraordinary monument of history of sciences, a very epistemology by its very self and perhaps the most enlightening knowledge of man's search for knowledge. In particular, the new history of Indian astronomy leads us to discover how and why Aryabhata was the leading astronomer of the scientific astronomy in India and furthermore how and why he will soon be a great figure in the history of astronomy in general. Aryabhata's work was more accurate and advanced than that of Claudius Ptolemy." Regarding the year of

---

**A Concise History of Science in India*, INSA, P-88

Aryabhata's birth, he himself said in his famous treatise *Aryabhatiya*, "60 *yugas* of 60 years and three *yugapadas* (*Satyuga*, *Treta*, *Duapara*) have gone by while he has been of 23 years." According to this (the only information available about his birth), he was born in 475 AD (60×60−3102−23=475) *Pattiputra*. Aryabhata asserted athat the earth rotates round its axis as well as round the sun. His other scientific contributions include: evaluation of π as 3.1416, evaluation of AP and GP series, square and cube roots of numbers, discovery of trignometric sine, accurate calculation(up to seventh decimal place) of days in a solar year. It is better than Ptolemy's calculation.

Aryabhata said that the eclipses were not caused by *Rahu* but by the shadow of the earth and the moon. He discovered the causes of solar and lunar eclipses, predicted the duration and extent of eclipses. He said that the moon was essentially dark and was illuminated by the sun. There are indications that he had written one more book (apart from *Aryabhatiya*) but it is not available. It is being thought that the book might have contained description of astronomical instruments used in his time.

Varahmihira and His Panchasiddhanta

Varahamihira, born in AD, 499 or 505 referred to the five astronomical systems in vogue in ancient India in his *Panchasiddhanta*—*Paulisa*, *Romaka*, *Vasishta*, *Surya* and *Paitamaha Siddhanta*. Four of these five *siddhantas* are not available in the original form now and we know about them only from the *Pancha Siddhanta*. *Paitamaha Siddhaanta* was probably written in AD 78 very much on the lines of *Jyotishavedanga*. *Vasishta Siddhanta* (probably compiled by Vishnuchandra) strove to locate celestial bodies by dividing the sky into 12 parts of 30° each. *Paulisa Siddhanta* was written on the basis of work by Paul of Alexandria. *Romaka Siddhanta*, written by Srisena was on the basis of Roman or Alexandrian sources. The originality of *Surya Siddhanta* is controversial. Some say that it was compiled before AD 400, some credit it to Aryabhata and some credit it to Varahamihira. *Surya Siddhanta* describes several astronomical instruments—the armillary sphere, simple gnomon or *canku*, clepsydra etc. In *Surya Siddhanta*, the Indian meridian was fixed at Ujjain. This contains discussion on equinoxes, solstics, eclipses etc. This mentions the distance between the moon and the earth to be $30\frac{7}{12}$ times the diameter of the earth.

The most awakening topic in *Surya Siddhanta* is the *sine-table*, which is the oldest in the world. The concept of *ardhajya* (or semi-chord) was borrowed in Arabic as *jaib* (or curved inlet) and then in medieval Latin as sinus (or a curve) from which a final term 'sine' emerged. In the same text, there are references to *Kotijya* (cosine) and *Utkaramajya* (versed sine) also. Dr. Bina Chatterjee said, 'the trignometrical ratio of 'sine' was unknown to Ptolemy, whereas the Hindus made constant use of it.' (*Journal of the Royal Asiatic Society of Bengal*, Vol. XV, No. 2, 1940, article on "Hindu Astronomy"). B.K. Sarkar observes: 'The mathematicians of India devised (1) the table of sines (2) the table of versed sines. The term sine is on Arabic corruption from Sankrit term *Shinjini*."

Brahmagupta was born in AD 598 near Multan. He flourished in Ujjain. He wrote the astronomical treatises: *Brahmasphutassiddhanta* in 628 AD and *Khandakhadyaka* in AD 664. He extensively dealt with the properties of cyclic quadrilateral, trapezium and the relation between their sides, diagonals and areas.

Mathematics

Besides Brahmagupta, several others *viz.* Lalla, Prthudaka, Mahavira (AD 850), Manjula (AD 932), Sripati (AD 1039), Sridhara (AD 1020)and Bhaskaracharya advanced the growth of mathematics in India.

Bhaskaracharya (born in AD 1114) the last astronomer-mathematician of repute in ancient India, wrote *Siddhanta Siromani* in AD 1150. This remarkable work consised of four parts: *Patganita* (arithmetic) or *Lilavati* (name of Bhaskara's daughter), *Bijaganita* (algebra), *Grhagnitadhya* (motions of the planets) and *Goladhya* (calculations concerning the sphere). The entire treatise is a happy blend of poetic literature and prosaic scientific thoughts. It covers a variety of topics. Some of the illustrations are:

क: पत्चनिघ्नो विहृत: त्रिषष्टया
सत्तावशेषो sथ स एव राशि:।
दशाहृत: स्यात्विहृत: त्रिपष्टया ।
चतुर्दशाग्रयो वद राशिमेनम् ।।

Lilavati, 266.

(What quantity is it which multiplied by five and divided by sixty-three, gives a residue of seven and the same multiplied by ten and divided by sixtythree, a remainder of fourteen. Declare the number). Answer 14.

'Out of a swarm of bees, one-fifth part settled on a blossom of *Cadamba*; one-third on a flower of *Silindhri*; three times the difference of those numbers flew to the bloom of a *Cutaja*. One bee, which remained, hovered and flew about in the air, allured at the same moment by the pleasing fragrance of a jasmine and pandanus. Tell me charming woman the number of bees.' Answer 15.

The Arabians came in the field of mathematics in the eighth century AD. In Arab, mathematics was called *Ilme Hindasa* (knowledge from Hind). The word 'zarb' (strike) for multiplication, was later adopted by the Arabs. The original words of multiplication, used in India, were *ghgat* (घात) and *heat* (हत्). The mere user of some Greek terms in Hindu mathematic by later scholar does not establish the originality of mathematical process involved. For example, from the Greek word *kona* and *trikona*, angle and triangle have been formed. But it must be carefully noted that in the *Sulbasutras* which are more ancient we have the word *prauge* (प्र-उग) for a triangle.

The eminent mathematician J.R. Newman has said, "India has from time to time produced mathematicians of great power. But judged by absolute standards of greatness of among all mathematicians of the East, the genius of Ramanujam appears to be supreme." Because of his poor English, Ramanujam (1887-1920) failed in Intermediate examination. He displayed unbelievable talent in mathematics, even before he reached high school. Financial difficulties compelled him to discontinue his college studies. With great difficulty, he got a clerical job, where his employer Sir Francis Spring quietly sent some problems worked out by him, to Prof. G.H. Hardy. Highly impressed by his talents, Prof. Hardy arranged for him a scholarship at Cambridge. Within five years of his stay there, he published 21 papers. He contributed research papers on the theory of numbers, Riemann's Zeta function, mock theta function, modular equations, theories of continued fractions, elliptic function etc. He was made a Fellow of the Royal Society in 1918. Because of acute T.B. he was advised to return to the warm climate of India, where he died on April 26, 1920.

Venkatraman Saraswati (1884-1960) was another remarkable scholar. He passed M.A. examination in eight subjects at the age of just twenty years, securing highest honours in all. He became Swami Bharati Krishna Maharaj. He was installed as Shankaracharya of Sharada Peeth in 1921, and of Goverdhan Math, Puri in 1925. After many years of research on mathematics in ancient Vedic texts, he constructed sixteen mathematical formulae and wrote a volume on each. Unfortunately, the manuscripts got lost from the house of one of his desciples. In 1957, in his old age, he wrote a summary of the voluminous work. It was published in 1965 by the Banaras Hindu University under the name '*Vedic Mathematics*.' The application of these formulae to most of the classical mathematical problems gives astonishingly short solutions.

Illustrations:

(1) The solutions for changing 1/19 to decimal form, by *Ekadhikena purvena sutra* (एकाधिकेण पूर्वेण) is:

$$1/19 = \cdot 0_1 5263_1 1_1 5_1 789_1 47_1 3_1 68421$$

(1) $$\frac{12X^2+9X+7}{3X+4} + \frac{12X^2+X+3}{4X-1} = \frac{24X^2+14X+3}{12X+1} + \frac{5X^2+6X+2}{X+1}$$

can be solved by *Sunyam Samyasasmuccaye* as:
(शून्यं साम्यसमुच्चये)

$$\frac{3}{3X+4} + \frac{4}{4X-1} = \frac{12}{12X+1} + \frac{1}{X+1} \text{ (By Paravartya)}$$

$$\frac{12}{12X+16} + \frac{12}{12X-3} = \frac{12}{12X+1} + \frac{12}{12X+12} \text{ (By Sunyam)}$$

$$24X+13 = 0$$

$$X = -13/24$$

CHEMISTRY IN INDIA

Chemistry: The science of Chemistry deals with the study of substances their structure, properties and the reactions that change them into other substances. Broadly speaking, Chemistry is a branch of science which consists of the study of the changes which matter is capable of undergoing. Chemistry developed latter than other branches of science such as medical science, astronomy, mathematics. This is a practical science in the sense that it is directly connected with experiments and their observations. Chemistry arose as a byproduct during the study of the creation of the universe, medicinal science, search for the elixir of life (or *Amarat*) and philosopher's stone (or *Paras Pathar*). Such develpments took place at different times in different places.

Alchemy: Theoretical knowledge and the technical abilities obtained in the middle ages through practical activities did not have a straight forward development, but have a classical background. With the advent of the Christian Era, the people developed certain beliefs such as that the Sun generates its image, gold, in the body of the Earth; the Moon, represents silver and the Venus represents copper etc. They also believed that the Sun, the Moon and other planets in the sky controlled the destinies of man and continued to help him to obtain the noble metals.

The word '*Alchemy*' has its origin in the Greek word '*Chemeia*' and the Arabic word '*Al.*' *Alchemy was the art of attempting to find a liquid– 'Elixir of life* (or *Amarat to cure all ills*) *and a stone—'Philosopher's stone* (*or paras pathar*) *to transmute the base metals into gold.* Such a quest existed in almost all countries at one time or other. The people who engaged themselves in this art have been named as *Alchemists.* Their search failed, but in the process, they made discoveries on which was founded the science of Chemistry. In the West, alchemy made its first appearance in Alexandria during the first century (AD). The fundamental premises of alchemy are of Alexandrian origin and may be set forth thus:

(i) All matter consists of the same ingredients.
(ii) Gold is the noblest and purest of all metals and silver is next to it.
(iii) Transmutation of one metal into another is possible by an alteration in the admixture of its elements.
(iv) Transmutation of base metals into noble metals can be achieved by means of Philosopher's stone.
(v) There may exist an *Elixir of Life* which will cure all diseases.

It was on these premises that people worked in secret for many centuries. There was no co-ordination between them. Although the earliest alchemists (AD 250-300) such as Zosimus, Democritus and Mary Jowess were people with some practical experience and its problems but later authors being too much obsessed with the idea of making gold, felt contented to write about alchemy without practising it.

Alchemy in India

In India, a religious philosophy called the Tantric Cult appeared in the fifth or sixth century AD. This came into prominence and vogue after the decline of Buddhism. This exercised a considerable influence on the society till the thirteenth century AD. Tantric cult was for liberation from sufferings and immortality for the body by various means such as observance of certain queer rituals centred around the worship of Siva and Parvati. Compounds of mercury were often used during such rites. In India, people were in search of a liquid '*amarat*' to cure all ills and a stone 'paras' to transmute base metals into gold. The various attempts used to be independent and secret. Lack of co-ordination was responsible for the slow growth of knowledge. Alberuni (AD 1031) in his *Indica* described a person by the name of Nagarjuna, a native of fort Daihak near Somnath, who lived nearly a century before him. Alberuni described him as a great adept in *Rasayana* or Alchemy and the author of a treatise '*Rasaratnakara*' that contained the substances of the whole literature on the subject. *Rasaratnasamuchchaya*, another work on the subject was composed around AD 1300. The name of its author in some texts is described as Vagbhatta and in others Asvini Kumar. Though the people failed to find *amarat* and *paras*, yet in the course of their efforts, they discovered a lot of chemical processes such as sublimation, distillation, extraction of metals, preparation of *Bhasma* and preparation of gun-power.

Though we belonging to the modern age feel like saying that alchemists made foolish attempts and they failed in their vain quest for the *amarat* (elixir of life) and the *paras* (philosopher's stone), yet they discovered (at a very slow rate) a lot of knowledge on which was founded the noble science of chemistry. Thus alchemy led to the invention of the science of Chemistry.

Chemistry: Certain amount of knowledge of chemistry and metallurgy existed in India even at the time (3000 BC) of Indus Valley Civilization. This is supported by the archaeological excavations (at the sites of Mohenjo-daro and Harappa) of coloured pottery, glazed seals, beads, bricks, cement, copper and bronze objects of household use and silver and gold jewellery. Later during the *Ayurvedic* period beginning from 600 years BC, progress was made in the preparation of herbal drugs, vegetable—acids and alkalies etc. because of their use in Ayurvedic medicines.

The question of *creation of the universe* was taken up by an Indian scholar *Kapila*, in the 7th century BC. He was born probably at Pushkara near modern Ajmer and lived at Ganganagar. He propounded the famous *Sankhya sutras* or Sankhya philosophy according to which primeval matter is made up of three basic entities *gunas* viz. *Sattva* or Essence, *Rajas* or Energy and *Tamas* or Matter. The creation of the universe starts by the action of energy on matter creating an inert material called *bhutadi* which changes into five different kinds of *tanmatras*—the entities charged with various kinds of energies. Then there occurred the formation of five different perceptible gross elements called *bhutas* vis. *akasa* (ether), *vayu* (air), *teja* (fire), *apa* (water) and *kshiti* (earth). These bhutas are composed of different kinds of *anus*. The *anus* were described by Kapila as the particles which are obtained when a thing is divided and subdivided until further subdivision is not possible.

The famous Indian scholar *Kanada* (also known as Aulukya and Kasyapa) lived around 6th century BC at Prabhasa in Allahabad. He propounded an *atomic theory* known as *Vaiseshika Sutras*. This is the earliest atomic theory that appeared in any part of the world. According to *Vaiseshika Sutras*, everything in the universe is made up of *paramanus*, the real entities which are obtained when a thing is divided and subdivided until further division is not possible. *paramanus* cannot be perceived through any of the organs of sense perception nor can they exist in a free state. Different kinds of *parmanus* have different characteristics. They are eternal and indestructible. Thus the *paramanu* is equivalent to the modern 'atom.' Discussions on the peculiar characteristics (*visesha* means peculiarity) of the different kinds of *paramanus* and their various combinations give the name *Vaiseshika* to this philosophy. According to Kanada, the universe can be placed under six categories, namely, *Dravya* (substance), *Guna* (quality), *Karman* (Action), *Samanya* (Generality), *Visesha* (particularity) and *Samavaya* (co-inherence). Further, substances can be subdivided into nine entities, namely, *Kshiti* (Earth), *Apa* (Water), *Kala* (Time), *Dik* (Stace), *Mana* (Mind), *Atman* (Soul), *Teja* (Fire), *Vayu* (Air) and *Akasha* (Ether).

Most of the Indian schools believed that the elements other than ether were atomic. Indian atomism was certainly independent of Greek influence, for Kapila and Kanada both lived far before Democritus. The Jains believed that all *anus* were indentical and that difference in the character of the elements was due to the manner in which the *anus* combined. This is very near to the modern approach that the quality of an element depends upon the arrangement of the electrons in an atom of the element. The *anu* was generally thought to be eternal. But some Buddhists conceived of it not only as the minutest object capable of occupying space, but also as occupying the minutest possible duration of time, coming into being and vanishing almost in a trice. Thus the *anu* of Buddhists in some measure resembles the quantum of Planck. The Vaiseshika school thought that before combining to form material objects, *anus* make primary combinations of diads and triads. This is the doctrine of molecules. Indian atomic theories were not, of course, based on experiment, but on intuition and logic. They were not universally held. Looking at the early developments of atomic theories in other parts of the world, one has to admit that the atomic theories of ancient India were brilliant imaginative explanations of the physical structure of the world.

In the 6th century BC, it was realized by *Gotama Akshhpada* an ancient Indian philosopher scientist—that there are certain basic principles for research and investigation in any subject. He systematized these principles in the form of *Nyaya Sutras (nyaya* means analysis). According to Nayaya Sutras, there are four steps in the method of establishing the true indentity of a fact, a phenomenon or an object. These are *pratyaksha* (perception), *anumana* (inference), *upamana* (comparison) and *aptavakya* (testimony).

Since vedic times in India, Chemistry has been the handmaid of medicine of which "the oldest literary movement is the *Atharvaveda*," according to Prof. Macdonel. Not only was medicine associated with chemistry but in ancient times Astrology had also something to do with chemistry in as much as the planets, Sun, Moon, Saturn, Jupiter, Mars, Venus and Mercury were associated with gold, silver, lead, tin, iron, copper, and mercury respectively. *Atharvaveda* contains references to these metals being used in germ-therapy.

In ancient Hindu texts, we have a lot of information on filtration, solution, crystallization, distillation and sublimation. Substances such as oxides of copper, iron and zinc, sulphates of iron and copper, gold amalgam, white lead, dyes with a large variety of vegetable products, were fully dealt with in the Hindu texts. *Rigvedic* people were familiar with the extraction of metals such as gold, silver, copper and making of bronze. They knew tanning of leather, dying of woollen textiles, making of fermented (*Soma)* and alcoholic (*Sura*) drinks. They knew the manufacturing of soap, starch, glass etc. The chemical composition of *Somalata*—and *Somras* (सोमरस) —the famous herbal tonic of the gods which gave health and longevity were quite well known to the Indian Vedic Sages. The entire Ninth section of the *Rigveda* is in praise of this Soma.

The preparation of *Makara-Dhvaja* is a landmark in the history of ancient Hindu chemistry. It is a celebrated medicine which was known as a cure for almost all ills. This is prepared by taking one parts by weight of gold leaves and triturating with eight parts of mercury. To this paste is added, 16 parts by weight of sulphur and triturated in a mortar and pestle to obtain a black mass. This is then heated so that excess of sulphur goes off and the sulphide of mercury formed gets sublimated to give a dark red coloured substance. The use of metals is frequently mentioned in the *vedas*. For example, Gold (हरित), silver (रजत्), copper (लोहितास) and iron (कृष्णयस) were used in medicines and for coats of arms etc. Foreigners have eloquently admired the art of the Indians in metallurgy. Magasthenes wrote that the Indians were well skilled in arts. Fergusson said, "The Kutab Minar of Delhi opens our eyes to an unsuspected state of affairs to find the Hindus at that age capable of preparing of an iron pillar larger than any that have been prepared even in Europe upto a very late date. ... It is almost equally startling to find that after an exposure to wind and rain for fourteen centuries, it is unrusted, and the capital and inscription are as clear and sharp now as when put up fourteen centuries ago." This iron pillar weighs more than six tons. Iron pillars of Bhubaneswar (540 AD) and Konark (900 AD) have equally withstood the test of time. Solid copper bolt in Ramapura Ashoka Piller (3rd century BC), pure copper Buddha at Sultanganj made (400 AD) by casting, detailed description on zinc matellurgy in *Rasarnava* (1200 AD) and *Rasaratnasamuchaya* are distinct evidences of the lofty attainments in non-ferrous metallurgy in ancient India. The sanskrit name used for metallurgy was *dhatuvidh* or *lohvidh* (धातुविद या लोहविद).

The period from 500 AD to 1200 AD is called 'the tantric period.' In this period the growth of knowledge was quasi-scientific. The scholars were engaged in finding some liquid (*Amarat*) which could cure all ills and a stone (*Paras*) which could transmute all base metals into gold. Chemistry developed as a byproduct of this pursuit. Nagarjuna (8th century AD) was an eminent physician alchemist. His treatise *Rasaratnakara* cantains details of the apparatus for sublimation, distillation, extraction etc. This also contains extensive uses of red sulphide of mercury (*makaradhvaja*) and black sulphide of mercury (*Kajjali*). The preparation of *Bhasma* in which the mineral is subjected to a purification treatment and differential thermal analysis, is an old feat of Hindu Chemistry. The red hot metal is plunged into liquids like butter milk, sour gruel, cow's urine (गोमूत्र), sesamum etc. Later the metal is converted into ashes for use as medicinal tonic.

Gun-powder was manufactured in ancient India. The *Sukraniti* stanzas 201-202 describe the formula of gun powder as:

Take five palas of saltpetar, one pala of sulphur and one pala of charcoal prepared from the wood of Calotropis gigentea and Euphorbia nerifolia, by destructive distillation, powder them and mix them intimately and macerate them in the juice of the above named plants and of garlic. Dry the mixture in the sun and pulverise it to the fineness of sugar. Gun powder is thus obtained. If the fine powder is to be used for a gun, six or four palas of saltpetre are to be taken, the proportion of charcoal and sulphur remaining the same.

Nitric acid and sulphuric acid (*gandhak ka attar*) were known in India for centuries. The methods of preparation are described below.

(i) *Sulphuric acid:* Take saltpetre 20 parts and alum 16 parts. Take the acid liquid from the leaves and stem of Bengal horsegram, 18 parts. Mix and distill with an increasing heat till the whole of the acid is condensed in a receiver.

(ii) *Nitric acid:* Take comon salt 8 parts and alum 6 parts. Take the acid liquid from the horsegram. Mix and distill with an increasing heat till the whole of the acid is condensed in a receiver.

It is asserted by western scientists that the phosphorescence of diamond was first observed in 1663 by Robert Boyle but this property of diamond was already known to Indians. Bhoja (11th century AD) mentions this property, cf. *Andhekarey ch deepytey* (अन्धकारे च दीप्यते).

HISTORY OF MEDICINAL AND BIOLOGICAL SCIENCES

Beginning of Biology

The term biology was coined around (1800) (AD) from the Greek words *bios* meaning life and *logos* meaning reason or 'to study.'

The eminent medical historian Payne remarked: "The basis of medicine is sympathy and the desire to help others and what-ever is done with this end must be called medicine."

In fact medicine arose out of the primal sympathy of man with any living being, out of the desire to help those in sorrow, need and sickness. This sympathy has been one of the main inspirations, throughout the ages, for the development of medicinal and biological sciences. Biology, the Science (study) of living individuals, is most closely linked to the production of food and prevention of disease.

If man be wiped out, it is extremely improbable that anything very similar to him would ever evolve. This statement is quite meaningful and helps us to imagine how long and complicated has been the period of evolution of man. The meaning of human life and the destiny of man cannot be seperated from the meaning and destiny of life in general. "WHAT IS MAN?" is a special case of "WHAT IS LIFE?" Further it is interesting to know HOW OLD IS LIFE? Though we do not know the answer, yet we have some interesting clues. Apart from fictions, life can be no older than the Universe.

Investigations in such disciplines as astronomy, geology, oceanography and steller resources give the age of the universe as 2,00,00,00,000 years. According to ancient Indian astronomy, the age of the universe on 12th Feb. 1977 was 1,96,08,53,079 years.

Then what about the question "HOW DID LIFE ARISE?" Again, the honest answer is that we do not know. The mystery is being cleared by recent studies on the chemical activity of living particles of viruses and of genes, the submicroscopic determinations of heredity and growth. Current studies suggest that it would be no miracle, not even a great statistical improbability, if living molecules appeared spontaneously under special conditions of surface water rich in the carbon compounds which are food and substance of life. The occurence of such waters at early stages of the planet's evolution is more probable than not. This is not to say that the origin of life was by chance or by supernatural intervention, but that it was in accordance with the grand, enternal physical laws of the universe.

The building blocks of life are proteins. These are made up of amino acids, which are built around the molecules of amonia. Scientists have duplicated the conditions that prevailed at the time of origin of life with an atmosphere containing hydrogen, ammonia, methane, water vapour, carbon dioxide and nitrogen (oxygen came later into the atmosphere in considerable quantities only after the evolution of plants). In an experiment conducted by Stanley Miller in 1953, these conditions were created and amino acids and other moleculer characteristic of life were spontaneously formed out of the gases. Further experiments created proteins. In 1965, a team at the University of Illionis succeeded in producing a virus which stands at the threshold of life (A virus is a tiny structure possessing the power to multiply itself indefinitely and to undergo mutation but can not consume nutrients and excrete waste products). It is expected that biological research will soon produce a living cell.

Many people believe that evolution is a natural process of development in due succession like the unfolding of a bud into a flower or the growth from chlidhood to manhood. They believe that evolution does not mean transformation of one kind of life into other kinds of lives, as from a fish into a fowl or as from an ape (or monkey) into a man. The *Encyclopaedia Americane* says, "Biologists are now not only virtually in unanimous agreement that all life derives from a preceding life, but also that the parent organism and its off-springs are always of the same kind." All these reasons corroborate the well established scientific fact that a generalized structure can evolve into one or more specialized structures but a specialized structure cannot evolve into a different specialized character.

Regarding evolution of man, the common idea that he has descended from an ape like a chimpanzee or the gorilla is totally eroneous. Out of the creatures of reptilian line, only two species evolved into creatures having some specialized features. One of these evolved into birds and the other into mammals. In the mamals, only one species became primates and then man. The remote ancestors who preceded both and ape, evolved into two lines, one leading to the authropoid apes or pongidae (chimpanzees, gorillas and orang-utans) and the other to the Hominidae, leading through Australopithecus, Homoerectus and man. The divergence occurred some thirtyfive million years ago. The possible ancestor of the Hominidae line is called Propliapithecus and its fossil remains were found to be quite different from the possible precursor of the ancestors of the modern apes, Aegyptopithecus, whose fossil's jaw was found to belong to the same period.

There are some authorities who consider Proconsul, a creature which lived about twenty million years ago, as the ancestor of both man and the anthropoid apes. Whichever was the ancestor of both the lines, the point to note is that it had a generalized structure (having none of the specialised features of the man and the anthropoid ape). Man has evolved a straight back, long legs and a striding walk because our ancestors gave up arboreal life and took to hunting. The anthropoid apes, on the other hand, developed what is known as the branchiated condition which gave them arms, chest and musculature highly specialized for progress through the branches of trees.

The study of plants and animals really began as soon as the primitive man began roaming on the earth. As he depended on plants and animals for his existence, he, in due course of time studied them in order to discover which types he could utilize for food, shelter and clothing. He investigated which plants he could use to cure diseases and which animals he could use for work. He saw during hunting the complicated structure of the interior of dead animals and this made him think of his own interior.

Although primitive man accumulated a fair amount of knowledge about living creatures, this knowledge was often unscientific. The specific study of plants and animals began much later in several ancient cultures such as those of Babylonia, Egypt, Greece, China and India.

In the west, the early foundations of natural sciences were laid when Greek and Roman civilizations were at their peak. Greeks proceeded to the scientific and systematic work while Romans seemed to be interested more in the practical side of science namely Agriculture. Some of the information acquired by early civilized people, long before the Christian era, is available in the form of pictures and hieroglyphics painted on tombs, or carved in stone. These records indicate, without doubt that the Egyptians and Assyrians (4000 BC) were practical plant botanists. They cultivated medicinal, ornamental and food-plants such as roses, apricots, figs, dates, grapes, olives, wheat and barley. Some of the early man's impressions of the contemporary animals have survived in the cave paintings of France and Spain. Man decorated pottery, cloth, tools, etc. with animal figures. The pre-Inca race of Peru (3000 BC) was apparently the first in America to cultivate maize (corn).

Biology in India

In the year, 1922, archaeological excavations conducted at the sites of Harappa and Mohenjo-daro in Sindh (now in Pakistan) around the river Indus, have revealed the existence of the ruins of very ancient but well planned cities. These consisted of seven different layers of occupations and have been assigned the period 3250-

2750 BC. The excavated finds include certain cereals (grains), textiles and pottery. The various drugs discovered were silajeet, cuttle fish bones, horns of deer and antelope, corals and leaves of *neem* (margosa) trees. More recent (1976 AD) archaeological excavations, carried out at Haritalyanagar in Bilaspur district, India, have revealed that early man lived there almost fourteen million years ago.

Hindu System of Medicine has had a long history can be said without reservation. Meaningful advanced documentation of Indian medicine is available in the *Vedas*, particularly the *Atharvaveda*. Several other ancient Indian scriptures like *Ayurveda*, *Charaka Samhita*, *Susruta Samhita*, *Ramayana*, *Mahabharata* and *Upanishads* reveal that ancient Indians had a large fund of biological information. These included the knowledge of the structure and function of the bodies, plant and animals including human beings. Valuable information on surgical and medicinal treatment of various diseases is also available in them. The basic theory of the Hindu medicinal system comprises of *three Doshas* as enunciated belows:

(1) *Vata* — Bio-motar or motivational organization,
(2) *Pitta* — Bio-thermal or metabolic organization,
(3) *Kapha* — Bio-matrials organization.

According to them different diseases are caused by the change in the composition of these three *doshas*.

The medical school at the ancient Taksashila (Taxila) Visvavidyalaya (University) enjoyed special reputation. Its fame had spread far and wide. Many students came here to learn. The Taxila University came into existence in the 11th Century BC. Modern scholars have accepted its existence till 4th century BC. Atreya Rishi of eighth century BC and Jeevaka of sixth century BC were renowned physicians and teachers at Taxila. Atreya was an authority on *Ayurveda*, the Science of Longevity of man's life. Jeevaka served physician to Lord Buddha, and the kings Bimbisara and Ajatashatru.

According to the historian Sir William Hunter:

> "Many centuries ago, at the monastic medical university at Nalanda, near modern Gaya, Hindu surgeons successfully performed the operation of rehinoplasty and other feats of surgical skill. In old Hindu medical books, one may find the description of that branch of surgery which deals with the improvement of deformed ears and noses and the forming of new ones, one of the scientific additions to surgery in great hospitals in

> the large, modern cities in Europe at the present time." Furthermore. Zimmer rightly points out: "Charaka, Sursuta and Vagbhatta form the famous "Triad of the Ancients" and are considered the three great medical authorities of the subsequent ages."

The compendia of Charaka (First to second centuries AD) and Susruta (fourth century AD) known as *Charaka Samhita* and *Susruta Samhita* are the products of a highly evolved system which resembles those of Hippocrates and Galen in some respects and in others have even surpassed them. The former is a huge treatise on ancient Indian medicines, containing eight divisions *(Ashtanga Sthanas)* namely, *Sutra*, *Nidana*, *Vimana*, *Sharia*, *Indriya*, *Chiktsa*, *Kalpa* and *Siddha* sthanas. It discussed elaborately the ethiology of diseases on the basis of *tridosha* theory. It also provides a detailed description of the anatomy of the human body, various diseases including those of eyes, the female genital organs, normal and abnormal deliveries and diseases of the children. An idea of the various categories of practitioners of the healing art, physician and their fees, nursing, centres of medical learning, school of philosophy such as *Nyaya* and *Vaiseshika*, medical botany and classification of animal kingdom is also advanced. It describes various traditions, customs, legends, routine of daily life, habits of smoking and drinking, dress and clothing of the people of that era.

Sursuta Samhita is the main source of knowledge about surgery in ancient India. The present form of *Susruta Samhita* is the revised and supplemented version of the orginal book *Susruta Shalya Tantra* written by Susruta. It contains eight divisions namely, *Sutra*, *Nidana*, *Sharira*, *Chikitsa*, *Kalpa*, *Shalakya*, *Bhuta-Vidya* and *Kalamara-Bhrtya*. The depth presented in the various aspects covered, leaves no doubt that Susruta was a great surgeon and a teacher of repute.

He taught his students the surgical procedure first on dummies and subsequently on corpses. His techniques of dissection and analaysis of body structure are unique, practical and revealing of the structure of the body. His operations of making a nose and earloba, of Litholomy, of taking out the dead foetus, and abdominal operations are classical marvels. It must be reiterated that surgery was not considered a respectable profession prior to Susruta's plunge into this profession. He thus gave it status and organised it on sound footings.

Beside Charaka, Susruta, Atreya and Jeevaka other famous ancient Indian medical men were Dhanvantri, Bhardwaja, Patanjali, Vagbhata, Madhavekar, Vrnda, Dridhabala, Solihtra, Nagarjuna, Cakrapanidatta and Bhava Misra.

Despite their old history, Hindu biological and medicinal sciences could receive international recognition mainly from Alexander's time, when the Greeks came to know of its excellance. When the Arabs first came into contact with India, its knowledge spread into Arabia and thence to Europe.

Strabo, the Greek historian, has stated that Indians were great physicians and they were specially good at curing snake-bites. For the first time in the history of the world, Ashoka the Great built veterinary hospitals duly equipped with necessary medicines. The names of great surgeons like Nacula and Sahadeva can not be removed from the pages of history.

Ancient Indian Classification of Animals

A system of classification of animals was devised by Umasvati in the ancient Jaina work, *Tattva-thadhigamasutra*. Here, the number of senses possessed by an organism was taken into account, and the animal was placed in an ascending series according to this number. Umasvati's classification, was distinctly a bold advance and excelled contemporary efforts made in the western world dominated by Aristotle's ideas and contributions. In fact, in their attempt to introduce a system of classification, the ancient Indians appear to have made much more serious efforts to bring together known animals within the bounds of certain rational groups and achieved a larger measure of success than did Aristotle. Umasvati's classification consisted of:

1. *Those Animals which Possess two Sensess—Touch and Taste*
   - (i) *Apadika* — Worms without appendages.
   - (ii) *Nupurak* — Ring-like with pendants—Annelida.
   - (iii) *Gandupada* — Knotty-legged animals—Arthropoda (including Crustacea and Myriapoda).
   - (iv) Some kinds of Molluses, such as *Sanikha* (Conch), *Suktika* (pearl oyster) and Sambuka (spiral shell, many snails).
   - (v) *Jaluka* — Leeches (Hirudinea).

2. *Animals possessing three Senses—Touch, Taste and Smell*
   - (i) *Piplika* — Ants.

(ii) *Rohinika* — Red ants.
(iii) *Upacika, Kuntru, tuburuka,* — bugs and fleas.
(vi) *Trapusabiya* and *Karpasthika* — Cucumber and Cotton-weevils, lice.
(v) *Satapadi* and *Utpataka* — centipede and springtail.
(vi) *Trnapatra* — plant-lice.
(vii) *Kasthaharaka* — wood-destroyers e.g. termites or white ants.

3. *Animals possessing three senses Touch, Smell and Sight*
   (i) *Bhramara, Varate* and *Sarainga* — bees, wasps and hornets.
   (ii) *Maksika, puttika, damsa* and *masaka* — dipterous flies, gnats, mosquitoes.
   (iii) *Vrscika* and *nandyavarta* — scorpions and spiders.
   (iv) *Kita-pataiga* — flying and non-flying insects.

4. *Animals (man and the tiryakyonis) with five well developed and active Senses*
   (i) *Matsya* — fishes (Pisces).
   (ii) *Uraga* — limbless reptiles including snakes.
   (iii) *Bhujanga* — limbed, reptiles and amphibians.
   (vi) *Paksi* — birds (Aves)
   (v) *Catuspada* — quadrupeds (Mammalia).

Among the four divisions stated above the first three came under invertebrates and the fourth under vertebrates.

Jain and Buddhist scholars of 600 BC classified animals into (i) *Attihika* (having bones) and *Anattihika* (devoid of bones). This classification coincides with the modern classification of animals into Vertebrates and Invertebrates.

It is a fact that Indian physicians were called to Persia about AD 200 to give anesthesia for a painless operation. In ancient India ambulance vehicles were utilised to remove the injured soliders from the battlefield. One can not find the name of any such conveyance in European history before the commencement of Crimean War. The services of Indian Doctors like Manaka and others were requisitioned by Khalifa Harun al Rashid of Baghdad, when he was seriously confined to bed and Arab Physicians had lost all hopes of curing him. After recovery, the Khalifa himself requested Manaka to stay with him and translate *Ayurveda* works into Arabic. He also desired to call Indian Lady Doctors and mid-wives to write textbooks for his medical colleges.

Physical exercise had been recommended as a cure for diabetes in *Ayurveda*, as far back as 600 BC. This ancient medical assessment was confirmed recently (November 1, 1976) by Dr. Vranic of Canada in one of the technical Sessions of the 9th Congress of the International Diabetes Federation at Vigyan Bhawan, Delhi, India. He said, exercise enabled bigger intake of glucose by the body and more secretion of insulin into the blood flow and the capillaries.

Recently (1976) details of ancient medical systems including a well-developed science of "mental treatment" have come to light following the discovery of 10 old manuscripts from "Braham Tong Chug" *goomphas (monastries)*, the residence of the Head Lama of Arunachal and Tawang Monastery. The team of explorers was deployed by the Regional Research Institute *(Ayurveda)*, West Bengal, Central Council for Research in Indian Medicines and Homeopathy. Among these manuscripts, there is a one entitled: *Tsungnachho* containing *Shlokas* and *Mantras* on mental treatment, written in golden letters. Another manuscript *Tenguru*, contains datails of techniques of medical treatment. Yet another manuscript *Kengur* has *Shlokas* and *Mantras* describing the medical system of Ancient India.

Five other manuscripts, known to the residents of Tawang Monastery as *Passppasheradhar*, *Pharledu*, *Chhumpa*, *Getongpa* and *Shugso* are rich in *Shlokas* on medical treatment. A manuscript called Dachi (or Panjilla) explicates the technique of calculating periods of treatment for various ailments. All these manuscripts have been estimated to be over 1000 years old. The Central Council for Research in Indian Medicines intends to carry out research on the basis of knowledge in these manuscripts.

The Renaissance

After the dark ages, there was a revival in science and other areas of man's activity. There was a gradual growth of the scientific studies of plants and animals. In Europe, universities were founded in which professors lectured on different topics and students in their academic robes observed the demonstrations by assistants. Students themselves did little dissecting. Botanical gardens were popular and most European universities had gardens of medicinal and food plants.

After the middle of the sixteenth century, the research in biology was stimulated by five important contributions. The first of these was made by the Belgian doctor, Andreas, Vesalius who in

1543 published his chief work entitled *De Fabrica Humani Corporis* (on the structure of the human body). This was based on dissections and direct observations, rather than on previous assumptions of the so-called authorities. He stressed on making actual observations instead of blindly following assertions of others. So great was his zeal for personal observation and experience that he once stole the skeleton of a convict who had been hanged and whose flesh was eaten away by vultures. The *second* step forward was the discovery, in 1628 by the English Physician, William Harvey that blood circulates in the human body and that the heart acts as a pump. This led to rapid advances in the field of medicine. The *third* finding was the invention of the magnifying glasses which ultimately developed into the instrument Microscope. It made possible the study of those particles which escaped human eye-sight. After this development, biology progressed faster than any other branch of science. This discovery also helped the growth of other branches of science such as physics and chemistry. The *fourth* contribution, made by Robert Hooke in 1665, was that a thin slice of plant, when examined under a microscope appears to be made up of small cavities like those of honeycomb. Hooke called these 'Cells.' The *fifth* important discovery, made in Holland in 1676 by Antony Van Leewenhoek, was that there exists a world of microscopic plants and animals that had never been seen before. He first described unicellular organisms—Protozoa.

These researches brought a revolution in the field of Biology.

Important among various contributors were Antony Leeuwenhoek (1632-1723), James Lind (1716-1794), John Hunter (1723-1793), Edward Jenner (1749-1823), Georges Cuviar (1769-1832), Malthus (1766-1834), Rane Laennec (1781-1826), William Beaumant (1785-1853), Charles Darwin (1809-1882), Claude Bernard (1813-1878), I.P. Semmelweiess (1818-1865), Morton (1819-1868), Rudolph Virchow (1821-1902), Louis Pasteur (1823-1895), Gregor Mendel (1822-84), T.H. Huxley (1825-95), Lister (1827-1912), Mahendralal Sircar (1833-1904), Robert Koch (1843-1910), De Vries (1845-1935), Mechnikov (1845-1916), Iran Pavlov (1849-1936), Paul Ehrlich (1854-1915), Sigmund Preud (1856-1936), Ronald Ross (1857-1932), Jagdish Chandra Bose (1858-1937), Claude Bernard (1855), Bayliss (1904), Haffkine (1860-1930), Albert Schweitzer (1875-1965), Alexander Fleming (1881-1955), Frederic Banting and Best (1922), Birlal Sahni, J.B.S. Haldane, P. Maheshwari and Hargobind Khorana (b. 1922, Nobel Laureate 1968).

As a result, infectious diseases such as small-pox, puerperal fever, malaria, cholera and plague etc. are no longer lethal. Discovery of certain antibiotics and sulpha-drugs has reduced human suffering to a great extent. Certain theories have also been established viz. Cell-theory, Germ-theory of disease, Theory of Evolution, Theory of Inheritance and Gene theory, etc. The process like photosynthesis in plants and chemosynthesis in some bacteria have not only been discovered, but also understood to a large extent. Discoveries of vitamins and hormones have revealed the effects of natural deficiencies in the human body. These works have been greatly facilitated by the X-rays, which have enabled the biologists to peep into the body of living beings.

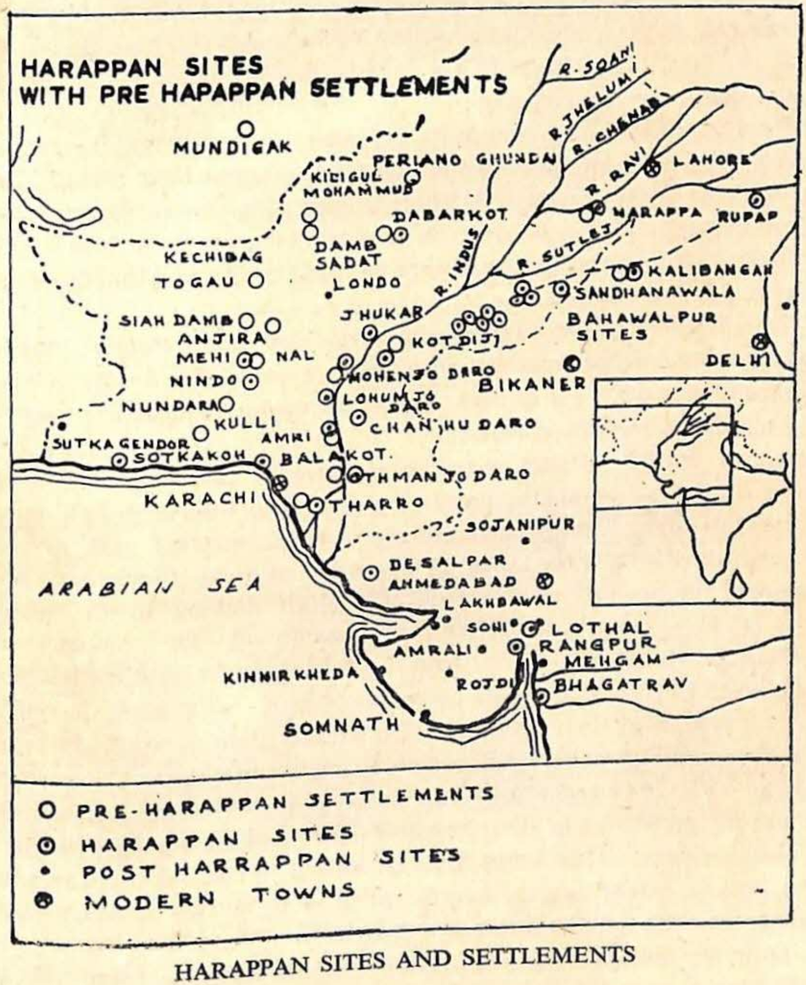
Biologists are now seriously attempting to produce test-tube babies. Most recently, bewildering success of man in producing two test-tube babies (both girls) has come to light. First of these, Louise Brown was born on July 25, 1978 in England and the second one Durga Aggrawal was born on october 3, 1978 in Calcutta, India. In both the cases, the fallopian tubes of mothers were in a block state and so fusion of sperm and egg was done in the laboratory rather than inside the womb.

It seems that producing a baby with a given set of characters is coming within man's reach. In fact, man is struggling to know *Brahamn* (the ultimate) scientifically.

INDUS VALLEY CIVILIZATION

Harappa and Mohenjo-daro

Archaeological excavations conducted at the cities of Harappa (in Montgomery District of Punjab) and Mohenjo-daro (in Larkana District of Sindh) around the river Indus, brought to light the ruins of very ancient and planned cities. Both these sites (500 miles apart) of former undivided India now lie in Pakistan. Large scale excavations were started at Harappa in the year 1921 (by Shri R.D. Benerji, an officer of Archaelogy of India) and at Mohenjo-daro a year later (1922) and continued with great intensity and vigour between the years 1928 to 1931 with far reaching results. From the seals excavated at Harappa, Mohenjo-daro and at the ancient umerian sites in Iraq, it appears that the civilizations of these lands were contemporary. Harappan seals bear inscriptions, but their characters have not yet been deciphered. Let us hope when that



HARAPPAN SITES AND SETTLEMENTS

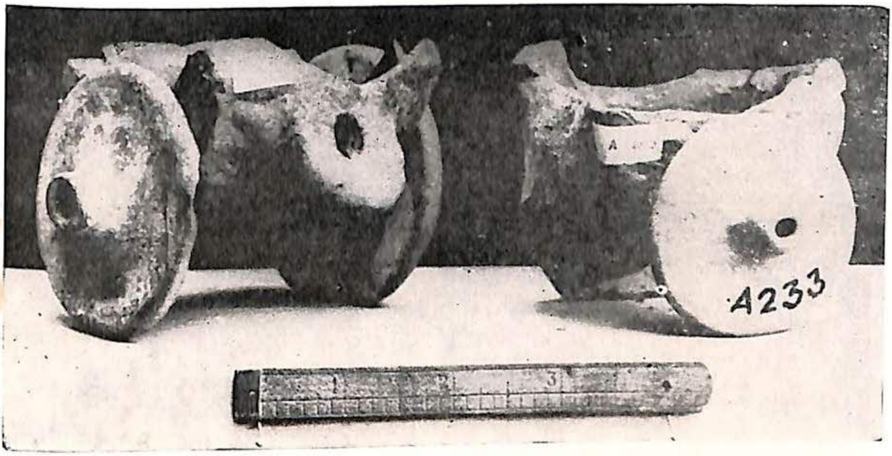
is done many problems hitherto awaiting solution will be resolved. Similar culture of Harappa and Mohenjo-daro, has come to be known as the "Indus" or "Harappa" culture. The Harappan culture covered a vast area of the countries that are now Pakistan and India —an area bounded in the northeast by the Himalayas, in the south-west by the Arabian Sea, in the west by Baluchistan, extending in the east to so far as the Ganges–Jumna Doab, and in the south-east to Saurashtra in India. Most of the remains known at present are concentrated in the Indus Valley.

Excavations at Mohenjo-daro revealed seven different layers of occupations. The topmost of these has been assigned the period 2750 BC and the others between 3250 to 2750 BC. The lower layers have been unapproachable because of being submerged in subsoil water. Cultural activity and progress were at their zenith in Mohenjo-daro during 2800 to 2500 BC.

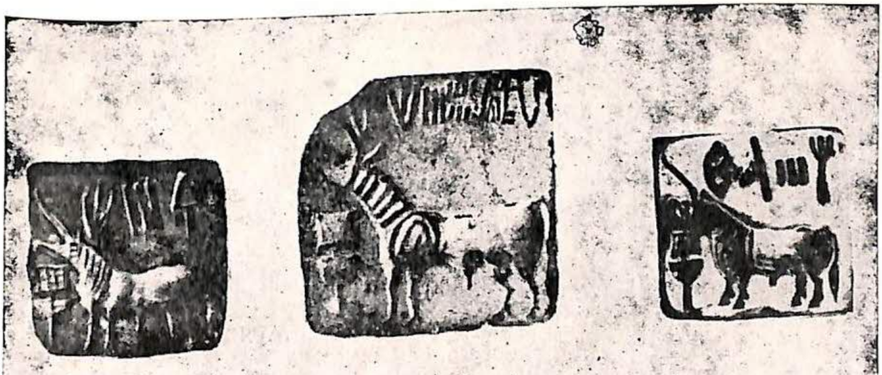
The discovery of these cities with their wide and straight streets, efficient and covered drainage, structurally comfortable houses with a bathroom in each, built of burnt bricks of various shapes has evoked the wonder of the whole world.

The excavated articles were certain cereals, textiles, tools, weapons, utensils, jewellery, pottery, glazed and inscribed seals and a variety of toys. *The toy carts are the earliest wheeled vehicles discovered anywhere in the world.* A discovery of great importance was made in the form of a piece of decayed cloth sticking to the inside of a jar in which a hoard of jewellery was found. This on analysis was found to be true cotton, thus establishing the cultivation and the use of cotton in India as early as the 3rd millennium BC. The technical skill of the craftsmen at this early date is obvious from the found gold jewellery and the other metal images, cast according to lost-wax (*cire-perdue*) process. According to this mode, the wax figure is made of the desired metal figure and then covered with a coating of clay. This when dry, is heated to run out the wax, and the hollow mould thus created, is filled with molten metal, which takes the shape of the original wax object.

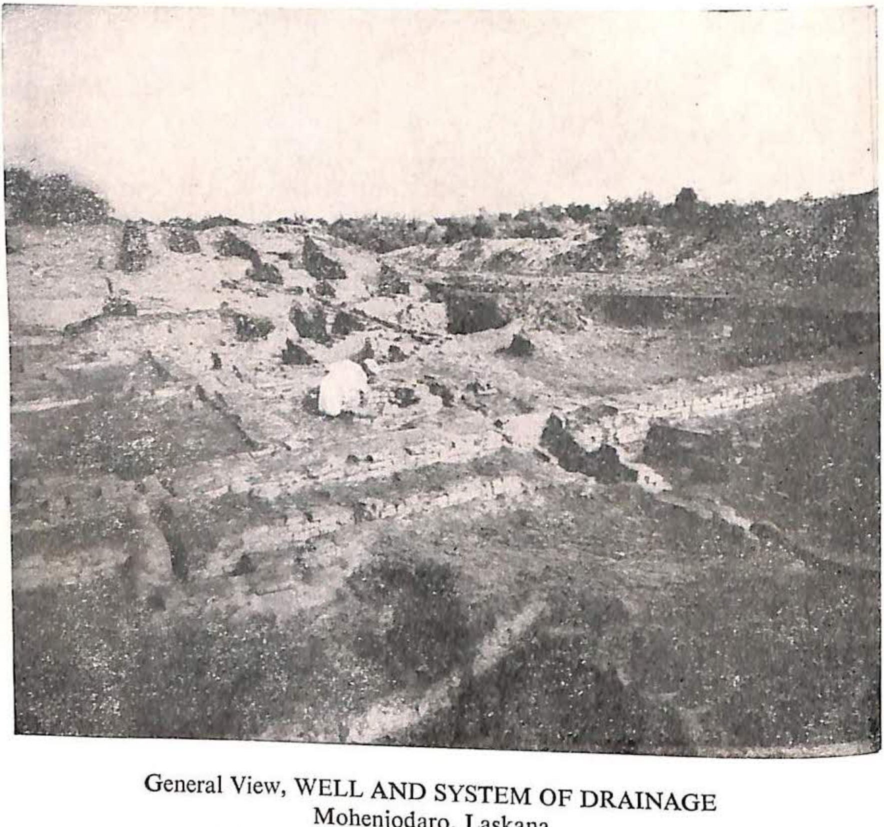
Different measures of weights for weights ranging from ·875 to 10970 gms. were also found. The most frequent weight found was that of 13·64 gms. which is approximately 16 times more than the smallest one. The usual measures of length discovered was a cubit (हाथ भर), being equal to modern 20·62 inches. The various drugs discovered were *silajit*, cuttle fish bones, horns of deer and



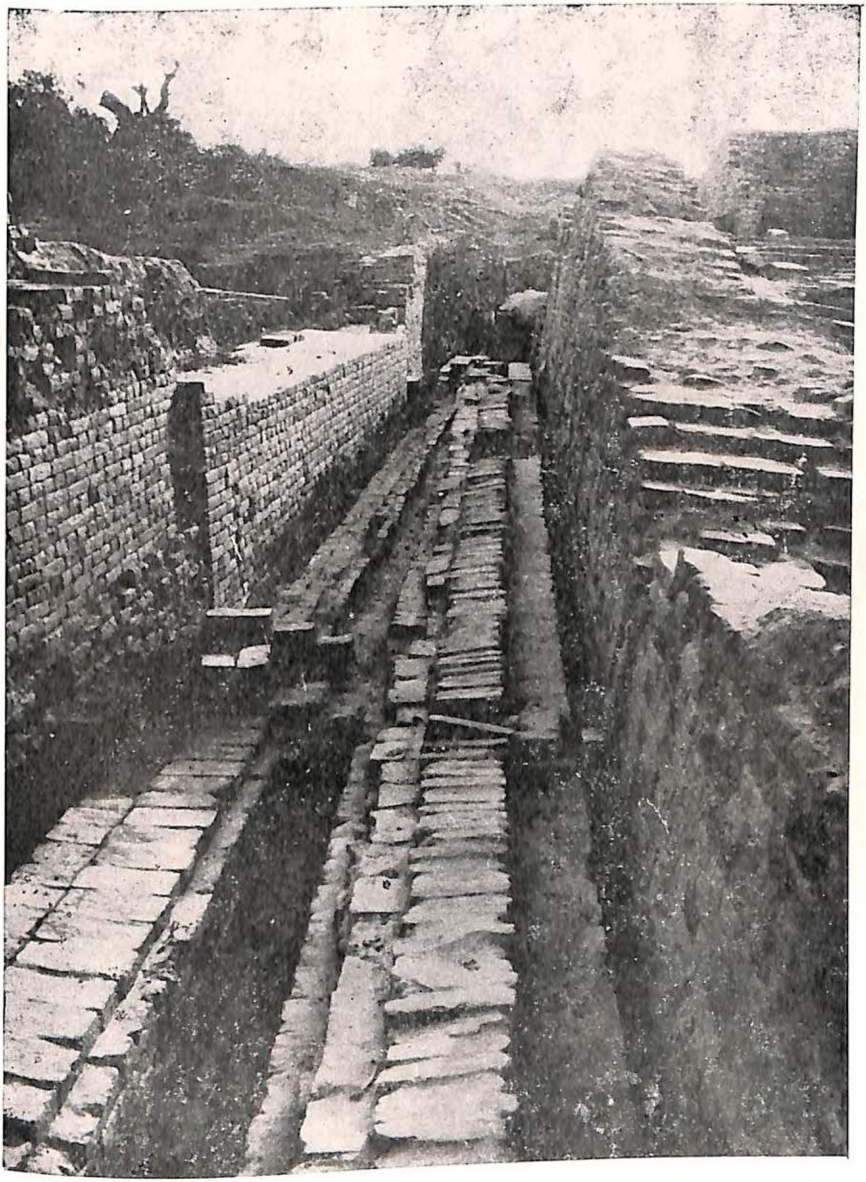
Two Terracotta TOY-CARTS, Montgomery
Earliest wheeled vehicales ever found
Courtesy, Archaeological Survey of India



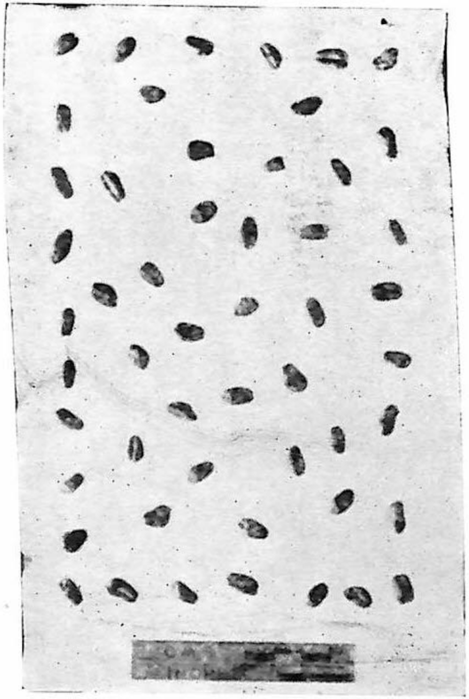
HARAPPAN SEALS, Montgomery
(Courtesy, Archaeological Survey of India)



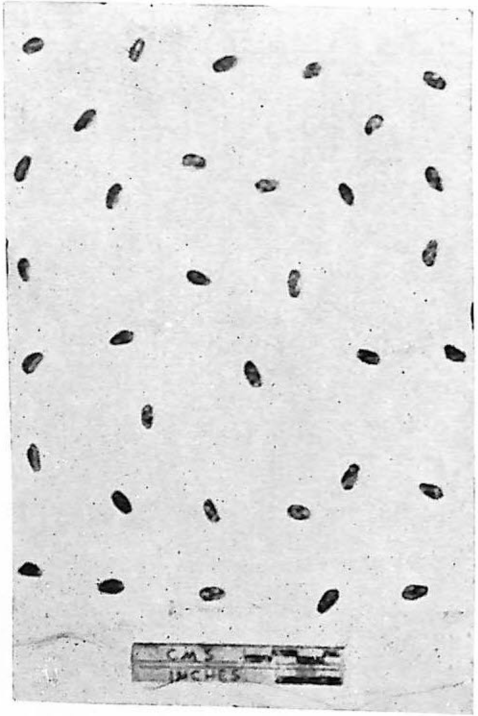
General View, WELL AND SYSTEM OF DRAINAGE
Mohenjodaro, Laskana
(Courtesy, Archaeological Survey of India)



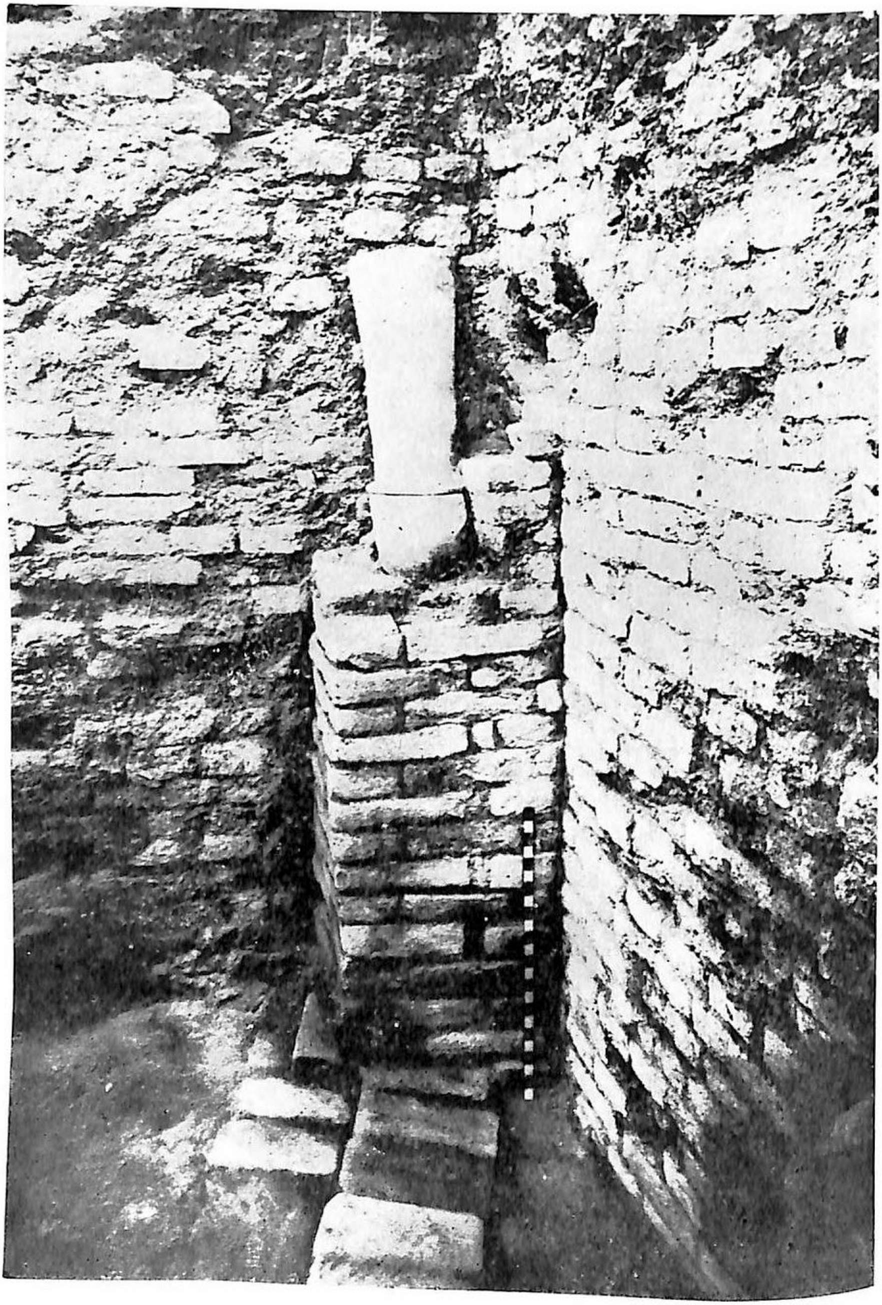
A LONG COVERED DRAIN in a straight street Excavation of 1924-25; DK Site Mohenjodaro, (*Courtesy, Archaeological Survey of India*)



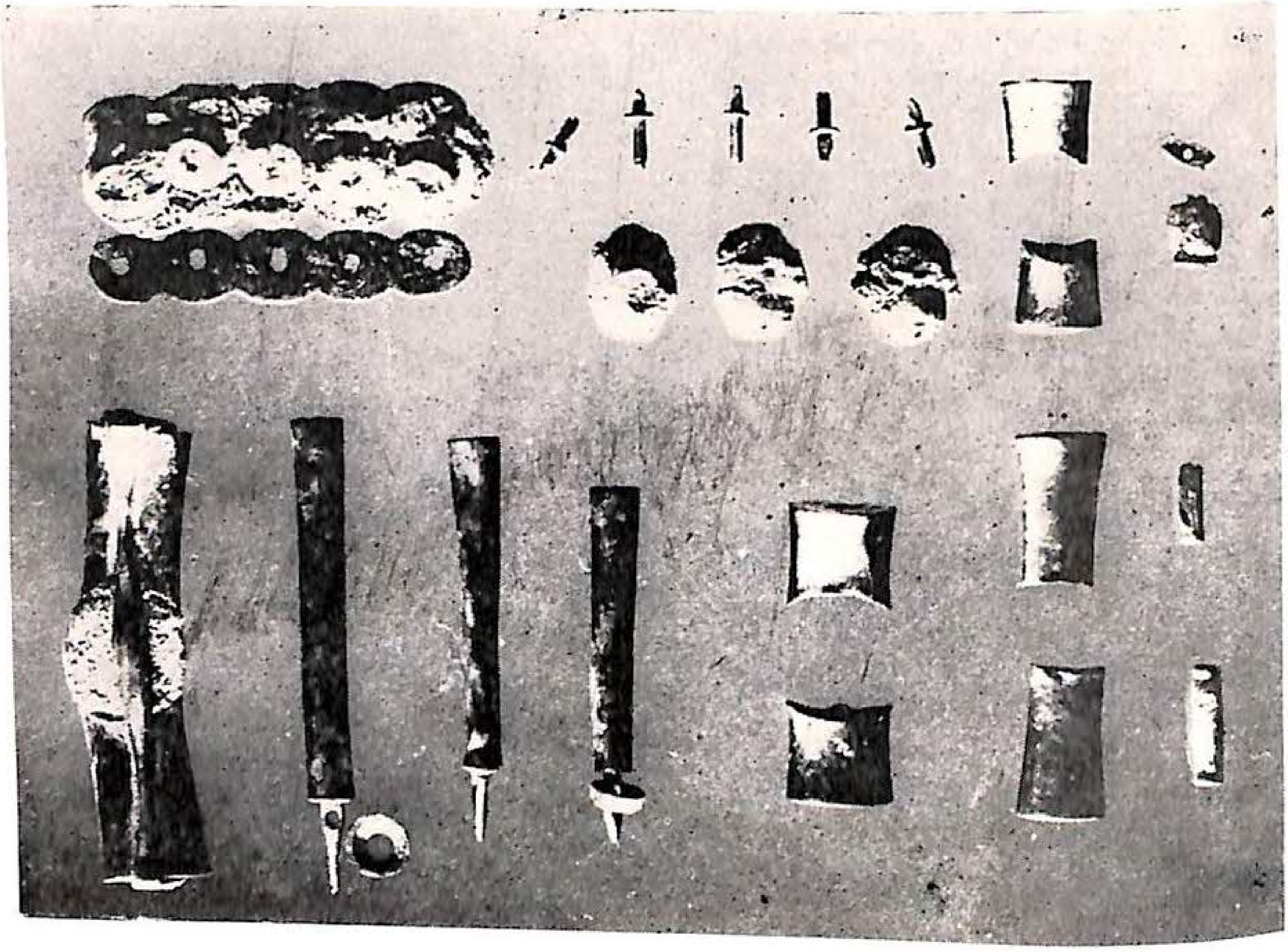
CHARRED WHEAT, Mohenjodaro
(*Courtesy, Archaeological Survey of India*)



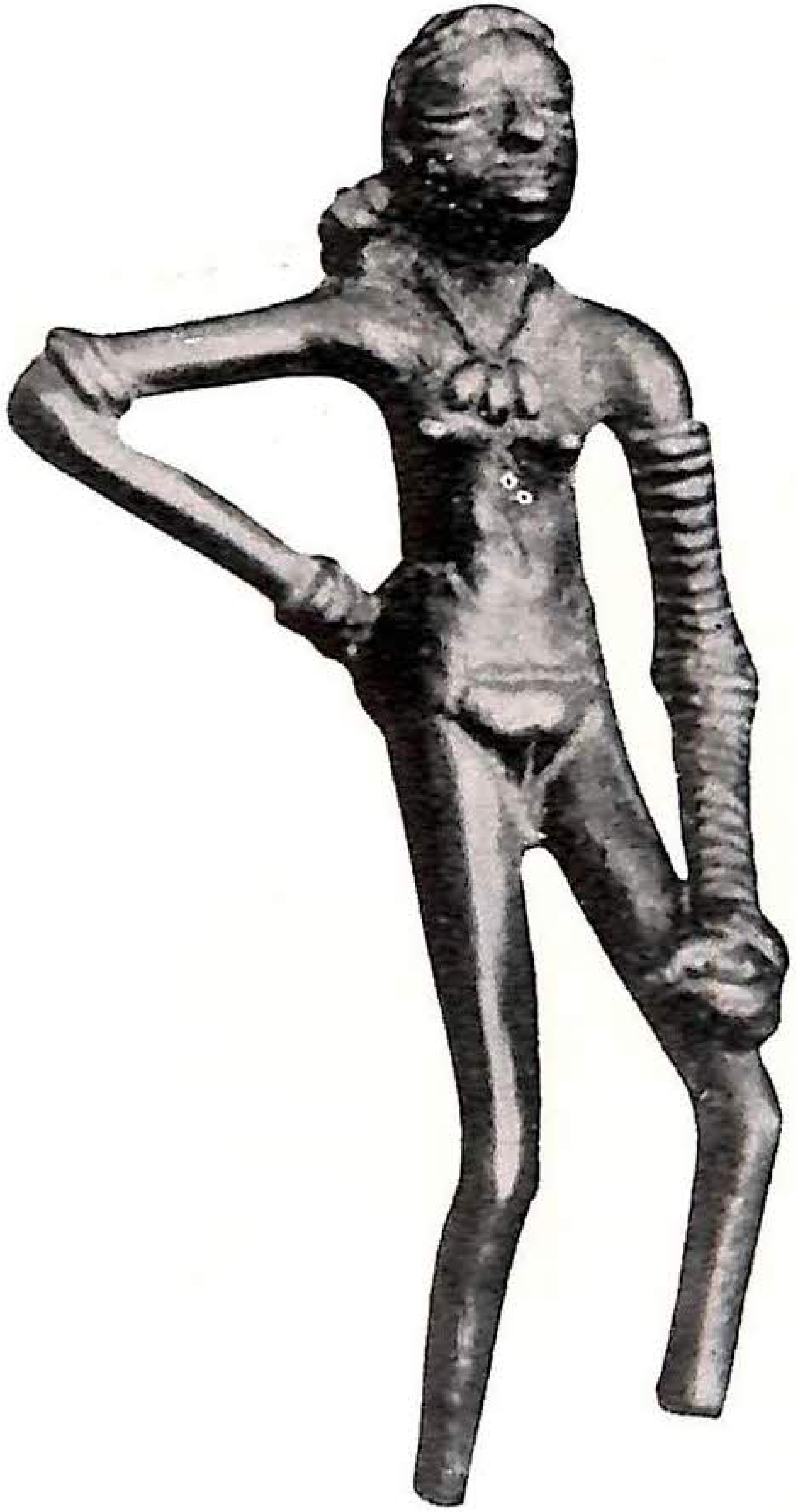
CHARRED BARLEY, Mohenjodaro
(*Courtesy, Archaeological Survey of India*)



VERTICAL-DRAIN PIPE WITH PIGOT AND SOCKET-JOINTS
(Courtesy, Archaeological Survey of India)



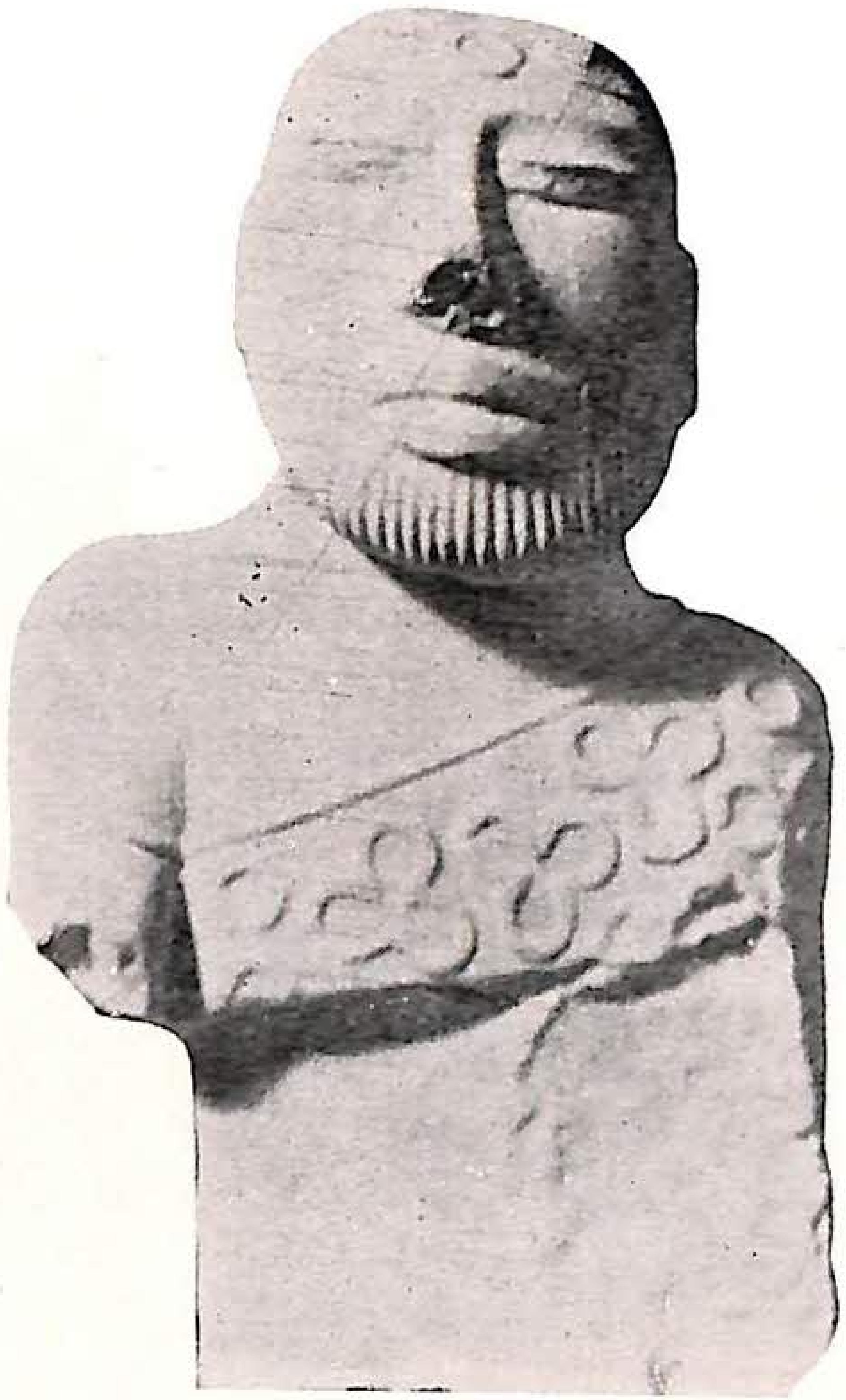
POINTED GOLD and other HEAD-ORNAMENTS, Mohenjodaro
(*Courtesy, Archaeological Survey of India*)



DANCING GIRL, *Bronze Statue*
2500 B.C. Mohenjodaro

(Courtesy, National Museum)

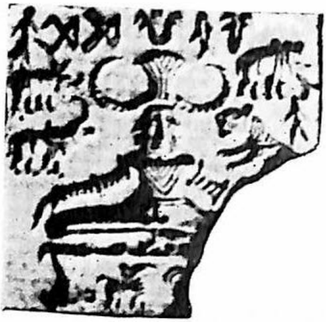
This world famous figure, is the greatest achievement of the metal workers of Harappan age



MALE BUST
Stone, circa 2500B.C., Mohenjodaro

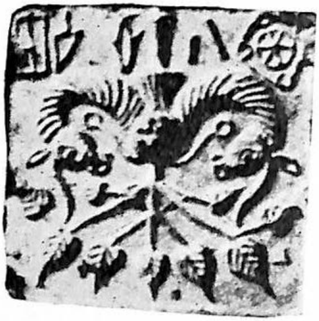
(Courtesy, National Museum)

This famous stone piece illustrates, the dress worn by the earliest civilized man in India, the trimming and cutting of moustaches and beard.



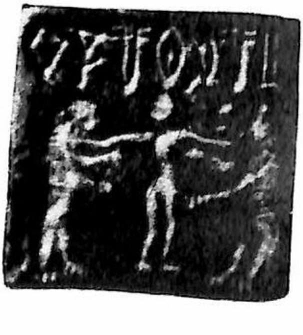
PASUPATI SEAL, Stone circa, 2500 B.C., Mohenjodaro

This seal showing a seated figure of a YOGI, probably Siva-Pasupati, surrounded by four animals, reflects the religion of the Harappan age.



SEAL—PIPAL TREE AND HEADS, 2500 B.C. Mohenjodaro

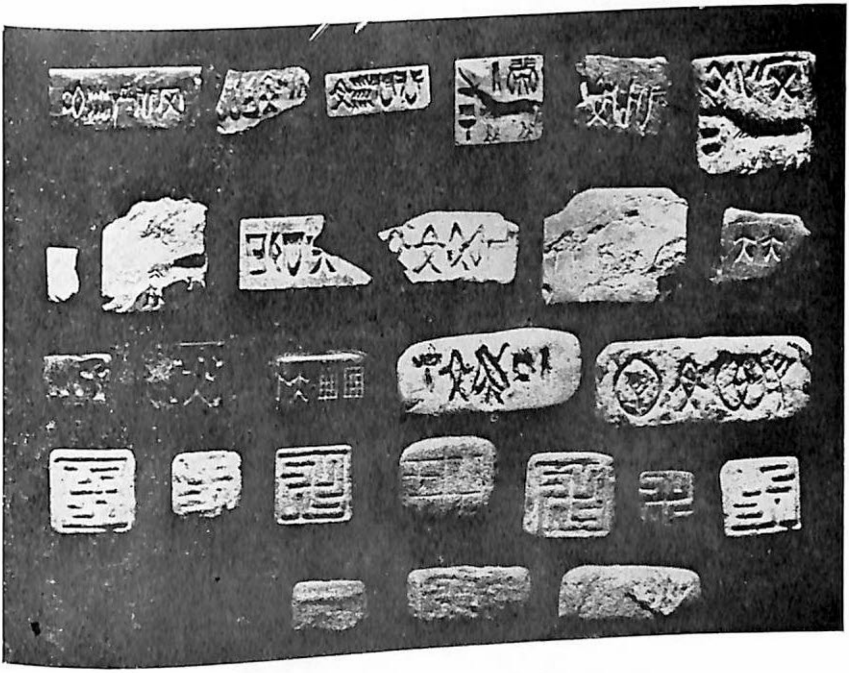
This shows two heads on either side of and almost entwining the pipal tree.



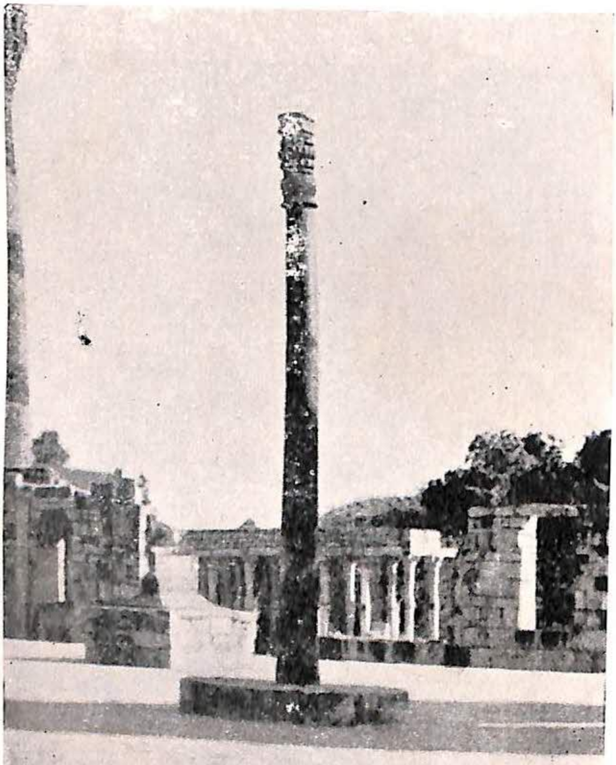
MAN — BETWEEN TWO TIGERS, 2500 B.C., Mohenjodaro

Each of the above three seals, has some legend in pictographic script yet to be deciphered

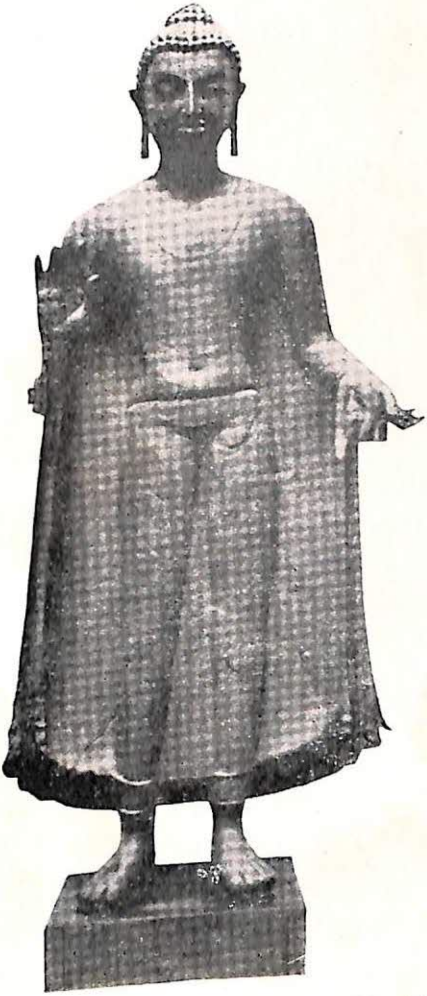
(*Courtesy, National Museum*)



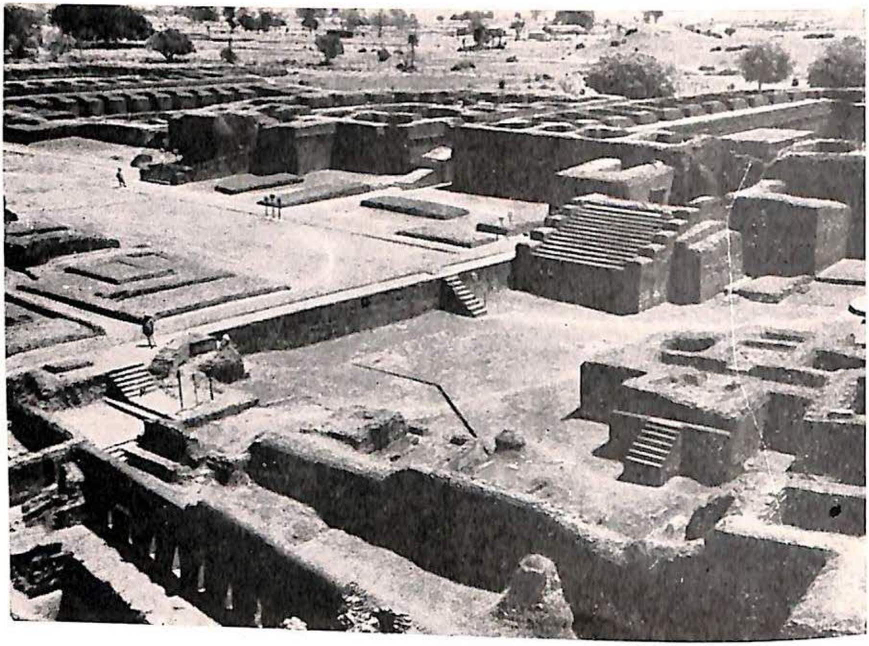
SEALS (27) from Mohenjodaro
(*Courtesy, Archaeological Survey of India*)



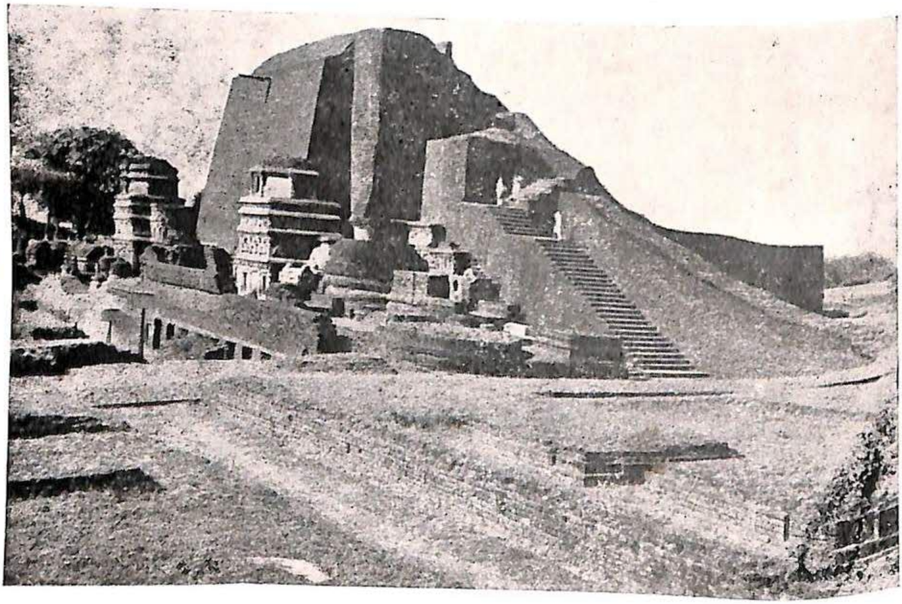
The Famous IRON PILLAR near Kutab Minar, Delhi
(*Coustesy, Archaeological Survey of India*)



COPPER STATUE OF BUDDHA, A.D. 400, Sultanganj
(Courtesy, Archaeological Survey of India)



VIEW OF MONASTERIES, NALANDA
(*Courtesy, Archaeological Survey of India*)



GENERAL VIEW OF STUPA, NALANDA (Site-3)
(*Courtesy, Archaeological Survey of India*)

antelope, corals and leaves of *neem* trees.

Also, only few and adequate skeletal remains have been found. Hence it can't be said with certainty as to what race or races the inhabitants of this civilization belonged. These people maintained close contacts with the outside world to their west and also with the whole of India except the far south.

Excavation work have revealed so far more than hundred sites in different parts of India, belonging to Harappan culture. However, work is in progress at only few of these sites. Recent excavations in India, in place like Lothal, Rangpur, Rupar and Alamgirpur, show the wide spread nature of Harappan culture, its high stage of development which suggests a very long tradition.

Archaeological evidence in the form of accurate stratigraphy is lacking as regards the end of the Harappan culture. Nothing comparable with Harappa—Sumeria link in about 2350 BC, exists to date the more recent Harappa levels at Mohenjo-daro.

Mohenjo-daro and Harappa ceased to be occupied by Harppans is certain and that the end was comparatively sudden seems well established. However, the inference, drawn by some scholars from a small number of skeletons of men who appear to have died violently, that the end of the civilization was due to invasion is surely too sweeping. It does not follow from the evidences that the men (whose skeletons have been found) were killed by invaders who might have overthrown the whole civilization.

The historical evidence furnished by the Harppan civilization is sufficient to put an end to the baised views of the interested historians and politicians that India was a land of the barbarians to which the Aryan came around 2000 BC. Though the extent of damage suffered by India due to the above propagation is immeasurable, yet it may not be too late if we set the historical and scientific perspective straight for ourselves and for the benefit of the entire world.

GREAT CENTRES OF LEARNING

Taksashila Vishvavidyalaya

A seat of learning in ancient India that flourished more than 3000 years ago and produced such giants in erudition as Panini famous grammarian for classical Sanskrit ; Atreya, an authority on Ayurveda ; Chanakya, a Political wizard of Arthashastra fame.

Taksashila (Taxila), situated near modern Peshawar, about 20 miles west of Rawalpindi (now in Pakistan), was the most important seat of learning in ancient India dating from 11th century BC. Modern scholars have accepted its existence till the end of 4th century BC.

Taksashila was the first and the greatest University of ancient world. The celebrated grammarian Panini who lived between 1100 and 900 BC had his education at this University. Panini is considered a genius and repository of erudition by Indian and Western scholars alike. The Ionian Greeks about 400 BC had only begun serious thinking (i.e. more than 500 year after Panini).

Taksashila University attracted students from all corners of India—Rajagriha, Mithila, Kashi, Ujjain, Kuru, Kosala...Its fame had spread far and wide in foreign countries; students from abroad used to come here to learn. The medical school here enjoyed a special reputation, but all arts and sciences could also be studied here under the most eminent professors (*Acharyas*).

Atreya, a well-known authority on Ayurveda, is said to have lived about eighth century BC. He was a great physician and renowned teacher at Taksashila. The science of medicinal plants was developed by him for the first time in India. He composed several works amongst which *Atreya Samhita* is very well known. His pupils Jivaka Kumarabhacca, Bhola, and Jatukarna, Parasara, Ksarapani and Hrita also compiled treatises based on Atreya's teachings. As a teacher of Ayurvedic medicine, Atreya is known to be unsurpassed.

Atreya enumerated six tastes as sweet, astringent, bitter, sour, salty and pungent and talked of the influence of each on the human body. He described the medicinal qualities of different kinds of water and the use of hot and cold water in various diseases, the physical and medical properties of various milks, sour gruel, sugar-cane, infusions from rice, barley and other grains, oils, fruits, herbs, alcoholic liquors made from molasses, honey etc. He described various animals, birds, fishes, snakes and discussed the properties of their flesh, and evolved principles of diet. He dealt with moral causes of disease and described various diseases in detail such as fevers, diarrhoea, dysentery, consumption, haemorrhage etc., and also their treatment. He also dealt with various antidotes against poisons.

The famous Jivaka, physician to the Buddha and the emperors Bimbisara and Ajatashtru, had his training at Taksashila, in the sixth century BC. He was said to be the son of Salavati, a courtesan of Rajagriha (near Patna), which was the capital of Magadha Empire in the reign of Bimbisara.

After his birth, Jivaka was thrown on a dust heap where people noticed that he was still alive (*Jivati*). This information was given to the Prince Abhaye, son of Bimbisara. The Prince gave him the name Jivaka and brought him up under his own care. This is the reason why Jivaka is also described as Jivaka Kumarabhacca, meaning "the one brought up by the Prince Abhaye." When Jivaka grew up, he learnt of his antecedents and without informing the prince he left for Taksashila. There he studied medicine for seven years under the world-renowned physician Atreya.

After completion of his studies, on his way to his home town, he could reach only up to Saket (in Faziabad, UP) because of the little money given by his teacher. There he was forced to earn for himself. The inexperienced young Jivaka treated in few minutes, a merchant's wife who had headache for the past several years by pouring *ghee* mixed with some drugs into her nose. He got a handsome reward which on reaching home, he presented to his patron prince. He cured King Bimbisara of his piles with just one application of medicine. He cured Emperor Chandapajjota (of Avanti kingdom) of his jaundice. He is said to have performed surgical operation on the head and abdomen as well.

He treated the Buddha for his wound on the foot as well as for an abdominal disease. Jivaka's fame as a physician brought him more work than he could cope with, but he never neglected his duties to the Buddhist monks. Many people afflicted with diseases and unable to pay for treatment joined the Buddhist ranks in order that they may receive his treatment.

Great care was taken in the selection of the candidates for admission in this centre of learning. The most capable teachers were on the selection committee whose members were called Dwara Pandits i.e. those who guarded the entrance. A candidate belonging to the family of physicians was preferred. The age at the time of admission to the medical studies was 16. The students were taught theory as well as practical of medicine, equal importance being given to both.

In the 4th century BC Chanakya (Kautilya) was a teacher at Taksashila. He was very unhappy with the king Nanda, who had insulted scholars of his state. So be decided to uproot the Nanda dynasty. Once he came in contact with a courageous child having inborn qualities of a ruler. He brought the child to Taksashila and educated him. This child, who became famous by the name of Chandragupta Maurya, had his training in political science, economics and administration at Taksashila. Under the guidance of Kautilya, he annihilated the Nanda dynasty and developed a strong empire. He got back the major portion of territories occupied by the Greeks.

Kautilya has described the economic conditions during the Maurya Age in his famous treatise *Arthasastra* (It is still considered as a standard socio-economic work). Kautilya's code contains a whole section on labour-management relationship. Artisans and craftsmen were protected by the State against any cruelty from their employers, and the merchants compensated for loss of merchandise by theft or robbery.

The Greeks were so enchanted by the stories about India that they even knew of a learned Brahmin of Taksashila whom they called Dandamis. When the Macedonian King, Alexander the Great came to India, he sent for Dandamis at Taksashila. But he refused to go to the King. Alexander agains sent his officer one Seleucus to him who threatened the Brahmin that Alexander the World Conqueror, would behead him if he refused to see him. But the learned Brahmin replid. "He has not as yet seen the other bank of the river Beas. If he successfully faces the brave Indian States beyond and still remains alive, we shall consider whether he is a world-conqueror. Alexander offers me land and gold, but go and tell him that sages like me look down upon such things. This motherland of mine provides me with everything I want...Go and tell him that he should issue these threats to those who are slaves of gold and power and are afraid of death...I won't come. Go away!" World historians are surprised at this little incident in the life of King Alexander the Great—so called.

Alexander swallowed the insult inflicted on him by Dandamis not because he was a great admirer of learning and generous to his enemies as the Western historians teach us. The reason was that his first fierce encounter with the Gana Republic of Puru (Porus) had frightened his whole army leading to a revolt to which Alexander had to succumb finally and withdraw from that Indian border leaving the dream of reaching Pataliputra unfulfilled. He died of an injury from an Indian arrow which had pierced even his strong armour.

Historian Vincent Smith has established that Alexander had carried out wholesale massacres of the Indian settlements including men, women and children for their refusal to surrender or willingness to be deported to Greece as slaves. Alexander was specially against learned men (Brahmins) and massacred them. Plutarch writes, "These philosophers were especially marked down for revenge by Alexander as they gave him no less trouble than the mercenaries... On this account he hanged many of them." There are records of such operations from the areas of the Punjab to the mouth of the river Indus which was the main seat of learning and civilization. The story of total annihilation of Brahmanic Gana Republic which fought Alexander to its last child and perished, is well known.

Later the Kings of Maurya dynasty were able to get back the major portion of the land occupied by the Greeks. Knowledge improved faster, due to the improvement in socio-economic condition. Big institutions were established by the kings where food and medicine were given free.

Fa-Hien, a Chinese pilgrim, who visited India in the fifth century AD has made special mention of such places.

The invasions beginning with the Greek, and followed by the Scythians, the Huns, the Mughals and the British until the middle of nineteenth century continued the process of devastation and ruin. Each invader destroyed many scholarly evidences of India's rich culture and scientific developments. Every one gave to Indian History his own colour. Due to the destruction of much important historical evidence and, of course, biased, motivated propaganda, the real picture of Ancient India got blurred and disfigured resulting in total confusion about ancient Indian thought and culture.

With a sharper focus on the true historical perspective and an unlimited pursuit of extant data, the situation is improving slowly. There is much scope for systematic scientific research to set the historical perspective about India straight.

Nalanda Vishvavidyalaya

The period from fourth century BC to seventh century AD was one of exchange of ideas with the outer world and of political propriety, social, cultural and scientific development inside India. During this period, medicine, astronomy and mathematics made remarkable progress.

In ancient India, one could get education by following any one of the following procedures:

(i) From a teacher by living and working with him in his house.

(ii) One could go to a *gurukula*, where the students lived together with the teachers in the schools situated in the forests away from human habitation.

(iii) One could join one of the great centres of learning located in the larger cities such as Taxila, Kasi (Varanasi) and Nalanda.

Liberal education and science were taught and practised in the monasteries and religious centres of Nalanda. The Nalanda Vishvavidyalaya was connected with monasteries, where people pursued astronomical and mathematical studies apart from theology. The available evidence shows its existence from 500 AD till 1200 AD.

Chinese pilgrims Hsuan Tsang (629-649) AD) and I Tsing (AD 675-685), who resided as students at Nalanda have given a description of this centre of learning.

They have described that Nalanda was a residential University with a population of 8,599 students and 1,510 teachers and other staff. It provided food, clothing, bedding, tuition and even medicine free to the residents. It was supported by liberal grants for this purpose by royal and private philanthropy. Hundreds of villages were attached to it and managed by it, and this provided many of the necessities of life.

To be a student of Nalanda was an academic distinction in itself and 'Nalanda brother' was respected wherever he went. For centuries the students of Nalanda went out to work in foreign countries like Nepal, Tibet and China to introduce to them the wisdom of Bharat and the texts in which it was embedded.

Foreign students from Korea, Mongolia, Takhara, Japan, China and Tibet also came here to learn. Of those who came to learn, only two or three out of every ten finished their studies successfully.

All these give an idea of the great reputation of learning in those days when travelling from one country to another was a difficult affair.

THE DECLINE OF INDIAN SCIENCE

India had reached the zenith of its glory in most branches of knowledge long before the times of Lord Budda. It is definetly known that the Indian Science had developed and achieved great eminence at a time when Europe was passing through the dark period of early middle ages. It was through the medium of the Arabian Sciences that some of these Indian Scientific concepts and inventions joined the mainstream of the renaissance science in Europe.

A long period of continuous invasions beginning with the Greeks, the Scythians' the Huns, the Mughals and the British plundered India not only of its riches and wealth but of its knowledge, too. Dwarkanath Tagore (grandfather of Rabindranath Tagore) wrote in a letter to the *Englishman* dated 6th December, 1838. "The Mohemedans introduced in this country all the vices of an ignorant, intolerent and licentious solidiery. The utter destruction of learning and science was an invariable part of their system."

This can be proved in many ways. The long period of political subjugation and lack of material power relegated India to a position of marked inferiority in the eyes of the western nations. Their historians judged India's past from her positons during British Rule, All this, gave birth to a slave mentality and inferiority complex in Indian minds. It is still present in that section of the Indian society which does not know about her own rich heritage. More discussion of ancient Indian scientific throught and further comments of some well known sincere and objective world scholars will expose the baselessness of the extreme view: 'the talk of Ancient Indian Sciences, is humbug and whatever rational element is present in them is that which was borrowed from foreign sources namely Greece, Rome and Arab.' The European scholars who, having vested political interest, in projecting a destorted image of India, cunningly implanted a belief: Some Indo-Iranian or Aryan tribes migrated from mountain passes of Afganistan into northern India; they clashed with the orignal inhabitants of India who were barbarians; they succeeded in taming and civilizing them in the cource of time. The baselessness of this implanted belief would be further critically examined in this book.

REVIVAL OF SCIENTIFIC STUDIES

The revival of scientific studies in India began with the foundation of the Asiatic Society in Calcutta, on January 15, 1784. The pioneering efforts for the revival of scientific studies in India, were made by Raja Rammohan Roy (born in 1774), Rajendralal Mitra (born in 1822), Mohendralal Sircar (1833-1904), Ashutosh Mukherji (1864-1924), Krishnamohan Banerji and Sisir Kumar Ghosh. They created a congenial climate for the growth of scientific research.

Prof. Ramchandra (born 1821) of Delhi, wrote a treatise on the problem of 'Maxima and Minima'. He was the first Indian to gain some recognition (after 700 years of dark age in India) as a man of science in the 19th century. Dr. Aghora Nath Chatterjee (F/o Mrs. Sarojini Naidu) was the first Indian chemist to obtain D.Sc. in Chemistry. He pointed out certain errors in the book *Stereochemistry* by Prof. J.H. Vant Hoff.

Ashutosh Mukherji (1864-1924), who became later the architect of the University of Calcutta, made important contributions. At the age of sixteen, he gave a new proof of the 25th proposition of Euclid Geometry. While a student he gave a new method for solving Euler's equation. In 1887, he published four papers on Monge's differential equation, His other papers include those on isogonal trajectories, hydrodynamies and elliptic functions. Asutosh Mukherji, Sir J.C. Bose, Sir P.C. Ray and many other Indian scholars used the forum of the Asiatic Society of Bengal to communicate to the general public, the results of their scientific investigations. As the Vice-Chancellor of the Calcultta University, Mukherji organized post-graduate teaching and research in science for the first time in our country.

The last quarter of the 19th century witnessed the emergence of more scientists in India. They came forward either to establish scientific institutions or to conduct scientific researches with great zeal and devotion. Even the government (British), scientific establishments began to realize the scientific capabilities of Indians. During the last ninety years, numerous researchers have been able to put India on the scientific map of the world.

Brain-Drain

A person who gets matured and educated in a country and he starts rendering his services temporarily or even permanently, is an intance of brain-drain. Over the last two decades, the growing incedence of brain-drain has caused incalculable harm to the economics of 'developing countries', and in particular to India.

The demand for Indian talents is increasing not only in Africa and Arab countries, but also in Europe and America. Besides being the first among the developing countries, India was the fourth among all the countries that supplied international experts to the United Nations Development Programme (UNDP) in 1975. Among 10,788 experts recruited by UNDP, 538 were Indians. Indian men and women of varied talents, including engineers, architects, teachers, doctors and skilled workers, are migrating to foreign countries in considerable numbers. Unfortunately, the epidemic phenomenon of 'brain-drain' (—the ceaseless emigration of Indian scientists to foreign countries) is spreading. It has posed a danger to the growth of science in India. In one year, America alone is reported to have taken as many as 7000 qualified Indians.

Brain-drain cannot be justified for the simple analogical reason that if the neighbours of a family are richer and have better living standard then the children of the family cannot be expected to start living with the neighbour forgetting their own parents.

India is a poor country and has to spent a lot to train its scientists, technologists and doctors. When a doctor leaves this country to settle down in America, it means a loss of Rs. 3,30,000 to India and a gain of Rs. 51,75,000 to America. According to a United Nations report, India suffered a monetary loss of Rs. 787 crores (875 million dollars) in 1970 following the emigration of scientists, engineers and doctors to the United States. Also, a paper presented to UNCTAD estimtes that the value of skilled migration from developing countries as a whole to the United States, Canada and the U.K. has been computed as £ 46 billion during the period 1961-1972. This comes to £ 3.8 billion per year which amount nearly equals the total flow of official development assistance from the developed to the developing countries during the same period. According to an estimate by Prof. Richard Titmus of the London School of Economics, from 1969 to 1977 the United States had saved £ 50,000 million by employing 1,50,000 doctors, scientists and engineers trained abroad. In terms of numbers, according to the latest available data, from the early 1960 to 1976 about 4,20,000 highly skilled professionals —engineers, scientists and doctors—had migrated from developing countries to the developed countries.

The loss of qualified professional cadres affects adversely the technological advancement of the developing states and accelerates that of the countries making use of this imported talent. *The brain-drain, therefore, amounts to a new form of exploitation of the poor countries by the former colonial powers.*

Many Indian scientists have obtained citizenship in foreign countries and are thus lost to Indian science. Prominent among them are Dr. S. Chandrasekhar (FRS) and Dr. Hargobind Khorana. Chandrasekhar was born and educated in India till 1930. He has been working (from 1930-36) at Cambridge, U.K. and from 1936 onward at Chicago, U.S.A. He accepted the American citizenship in 1953. In 1957, he received the highest national award on scientific achievement from the U.S. President. Dr. Hargobind Khorana, born and educated in India, has settled himself in U.S.A. He was awarded the 1968 Nobel Prize in medicine for his outstanding contribution in the field of Genetics.

Perhaps many Indians remain abroad for the reasons stated by Mr. Nehru, "for better inducements and facilities." But this is not the whole truth. Dr. Kurt Mandelssohm, F.R.S., of the University of Oxford in his talk on 'Science in India' praised Young Indian talents in science who were suffering from "lack of appreciation of their work, insufficient means for research; difficulties in obtaining equipment and last but not the least, pettiness and jealousy among collegues particularly the older ones." Prof. J.B.S. Haldane, who accepted Indian citizenship, expressed similar views, in his book *Science in Indian Culture :* 'All over the country, junior workers are regarded with jealousy by their superiors, who either discourage originality or steal their results. I recently saw a bibliography of publications by the head of a well known Indian laboratory. This 'remarkable' man had published over fifty scientific papers in one year. No single human-being before him has ever made discoveries at this rate. No doubt junior collegues had done most of this work or all of it, but their names were not mentioned.'

Tangible solution to the problem of 'brain-drain' appears to be two folded—to check and to tax. The developing countries from which brain-drain is there to the developed countries besides improving their own economy should inculcate greater sense of nationalism in the minds of their citizens. The other part of the solution involves the evolving a system at the international level where a country using the persons trained by the other country, to pay tax to the later. This part of the solution was first suggested by eminent economists, Prof. J. Bhagwati and William Dellafar in an article in 1973. The issue of taxing the brain-drain was also raised at UNCTAD—V held at Manila recently, but all that was decided was to ask the UNCTAD secretariat to prepare in-depth reports on the reverse transfer of technology.

It must be realised that the countries which are least affected by brain-drain are those which have a sense of national purpose, where prospects are high for professionals and technologists and their children, and where they are encouraged in the pursuit of their healthy ambitions.

India Emerging Scientific

India is the world's third largest scientific community but is the fourteenth largest country so far as output in scientific literature is concerned. Those connected with science management and science policy must seriously ponder over such problems. There must be an accurate assessment of the need and corresponding plans for raising scientific manpower of desired magnitude and quality. Consideration to the development of the talents in the scientists should be more than to the laboratories and equipment. The government of India (by providing suitable research facilities and handsome salaries) and the society (by utilising friendship and family relationship) at large must give a come-back-call to all the scientists settled in foreign countries. We must emphasis that the foremost duty of a scientist is to serve his own country where he has been brought up and educated. Afterall, he has to fullfil his duty towards science as well as towards his country.

India needs all the talent she can produce and for retaining this she should employ all the men and women who seek richer careers abroad. There are, however, many Indians abroad, especially those with close relatives in this country, who would ilke to be back home if favourable conditions are created for them to do so. Fortunately, the Government of India and bodies like CSIR and UGC have realized the gravity of the problem. Efforts are being made to facilitate the return of able Indians from abroad and to prevent a further exodus of such persons. All these efforts will encourage young scientists to join and enrich the profession of scientific research in India. Proper leadership can be made available from (1) scientists of established reputation (2) Government of India (3) professional organisations and (4) the society at large.

With increasing national urge among the Indian masses and with science departments of about 100 universities, over 200 technical colleges, 60 national laboratories, numerous research organizations sustained by public and private funds, it should be wishfully hoped that Indian youth will adopt scientific career and devote themselves for the upliftment of India.

INDIAN APPROACH TO LIFE

According to the Bharatiya Darshan (the Hindu Philosophy), the worldly objects are composed of two categories: *jiva* (the living) and *ajiva* (the non-living). The essential difference between the two is that the former possesses *atman* (soul) while the latter does not. The *atmans* of different living beings are different but are parts and parcels of the *parmatman* (the eternal and infinite cosmic spirit, God.) *Atman* has 14 qualities: cognition, pleasure, pain, desire, aversion, effect, virtue, vice, faculty, number, dimension, distinctness, conjuction and disjunction. Normally, every *atman* goes on changing its body (as a human being changes his clothes). It is believed that the *atman*, by its good *karmas* (deeds) merges with *parmatman* and thus attains *nirvana* or *moksa* (liberation of soul from the cycle of life and death).

Numerous examples of *human rebirths* have come to light. Scientists have started investigating it seriously. Some universities (e.g. University of Virginia, U.S.A.) have opened fullfledged departments for the study of this metaphysical concept.

It would be interesting to mention some of those factual cases which have been scientifically examined. Mardula Sharma (M.A. from Banaras Univ.), born in 1949, at Bangalore is a daughter of Shrimati Shanta Shastri. One day (when she was just two years old), while having a look at a plate containing litchis, she all of a sudden spoke and compared these with the litchis of her garden (in previous life) in Dehradun. She further told that her name was Munnu and Shrimati Satyavati Shastri was her mother. Her parents went to Dehradun and found the whole statement, a fact. In another case, Lagdi (born in 1902) wife of Kedarnath Chobey of Mathura, died after giving birth to a child. In 1926, she was reborn in Delhi. She was named Shanti Devi. When Shanti Devi was just three years old, she told many instances of her previous life. These were verified and found correct.

In other case, a news item about a four-year boy recalling his previous existence (Photographer--Surender Nath) appeared in a newspaper. A police officer (D.I.G.) read the news and rushed to the boy's residence. The boy recognised him as a Police Inspector (he was an Inspector at the time of Surender Nath's death in an accident). On the basis of what the boy remembered about the incidents leading to his death in his earlier life, the mystery enveloping the murder of a journalist (Mr. Iyer) was solved.

The truth of first two cases was scientifically examined by Dr. Ian Stewanson, Head of the Department of Para-Psychology, Virginia University' during his stay in India. He expressed his agreement over the Indian belief of Human-rebirth.

Psychologists have established an Indian belief that a dying man usually forsees his death. An American scientist, William Mendergal has quantitatively experimented that the mass of a man decreases suddenly by 50 gm. (approx.), when he dies. Dr. Gates, Dr. Henry Verahuk (French), Dr. W.J. Killer (English) and some Russian scientists have independently predicted (on the basis of their experiments) that there is some microscopic material which leaves the body at the time of death. This material has been named as *atman* in many ancient Indian texts. It has been described that *atman* leaves the body at the time of death and enters some other body and is ultimately responsible for a new being.

Death is an ever present possibility of human existence and may overtake it any time. So man must always be prepared for it. None of his gross belongings can be carried with him beyond death. What survives death must be regarded as worthy of human pursuit in preference to what perishes.

The vedic approach to life is that man's endeavour to proceed from mortality to immortality i.e. from *zero to infinity*.

त्मसो मा ज्योतिर्गमय ।
मृत्योर्मा अमृ ंत गमय ।।

(From darkness lead me unto light, from mortality lead me unto immortality).
The approach road is provided in the *Katha Upanisad*, II, 6, 14.

यदा सर्वे प्रमुच्यन्ते कामा ये ऽस्य हृदि स्थिता :
अथ मर्त्योंऽमृतो भवत्यत्र ब्रह्म समश्नुते ।।

(When all the desires cease which were cherished in his heart, then the mortal becomes immortal, then he attains here *Brahman*).

4

Scientific Method

Nature of Science

The spirit of rational enquiry has always been the main factor in the development of science. It is characteristic of all great religious thinkers and philosophers that their greatness is motivated by the same spirit of rational enquiry that drives the great scientist today.

The word '*Science*' has its origin in the Latin word *Scientia* or *Scire* which means knowledge. The failure to appreciate and understand the true nature of science has caused much misunderstanding and unjustified criticism of the value of its methods. Science is systematized knowledge based on facts or truths known by actual experience or observation. It attempts to observe and describe facts and relate them to each other. It may also be regarded as a thoughtfull search for reasons of natural happenings. Its conclusions are always subject to revision in the light of newly discovered facts. Some persons may think that science can solve all problems. They may criticize science because science and more precisely its branch biology can't explain fully what life is. Even if scientists cannot solve some problem completely, they may gradually approach the ultimate solution by correct application of scientific methodology.

Scientific method cannot be strictly defined for it is a varying process which develops with time. Before considering the pattern of modern scientific methodology, it would be worth while to consider the different important phases in its historical development.

Historical Development

Ancient Indian Scientific Methodology: Research and investigation in any subject, be it science, arts, philosophy or theology, consists essentially of certain basic principles. *These principles, for the first time, were investigated and formulated by an ancient Indian philosopher-scientist *Gotama* or *Aksapada*. These have been embodied in the form of '*Nyaya Sutras*' (*nyaya* means analysis). Akspada Gotama said to be contemporary of Kanada and Buddha, lived during the sixth century BC. Some scholars believe that he belonged to a period earlier than 600 BC. Local tradition in Mithila (modern Darbhanga in North Bihar, India) points out the place of his birth as a village called Gotamasthana, where a fair is held every year on the ninth day of the lunar month of *Chaitra* (March-April). This village has a high mound supposed to be the site of the hermitage of the sage Gotama. At the base of the mound is a water-spring called Gotama *Kunda*. Later some other scholars have worked on *Nyaya Sutras*. The *Nyaya Sutras*, for establishing the true identity of fact, a phenomenon or an object, consist of:

---

*S.N. Dasgupta, *History of Indian Philosophy*, I, p. 279.

(i) *Pratyaksha* (Perception)
(ii) *Anumana* (Inference)
(iii) *Upamana* (Comparison)
(iv) *Aptavakya* (Testimony)

(i) *Pratyaksha* (Perception), is the recognition and knowledge of the objects, produced by their contact with external sense organs of sight, hearing touch, taste, smell; with internal sense organs such as mind.

(ii) *Anumana* (Inference), is the knowledge of the objects through the apprenhension of some mark which is invariably related to the inferred objects. During this process, firstly, there should be a relation of agreement in presence (*anyaya*) between two things i.e. in all cases where one is present, the other should also be present. Secondly, there should be uniform agreement in absence between them (*Vyatireka*). Thirdly, no contradictory instance should be observed where one of them is present without the other (*Vyabhicaragraha*). Lastly, relevant hidden determining conditions (*upadhi*) and accompanying circumstances have to be taken successively, investigated and eliminated by repeated experiments and observations to establish an invariable concomitance (*vyapti*) between the mark and the character inferred. This is how one can obtain the knowledge which is valid and correct.

(iii) *Upamana* (Comparison), is the knowledge of the phenomenon or the object obtained by the establishment of a relation between a name and objects so named or between a word and its denotation. e.g. a child is told that an animal with such and such description is a horse. When he sees an animal for the first time with particulars which fit in with the description, he concludes, by comparison, that what he is seeing is a horse.

(iv) *Aptavakya* (Testimony) is a method of establishing the identity of an object *i.e.* the knowledge of the perceived and unperceived objects derived from the statement of authoritative sources viz. standard scriptures such as the *Vedas*, the sayings of the sages and the Research Journals. Here one must know as to how many interpretations, according to the individual way of thinking, have been put forward and accepted by various scholars and people, to whatever is written in the Vedas. These interpretations have been sometimes poles apart but that has not in any way infringed upon the profound veneration in which the Vedas are held.

As regards the practical use of Nyaya Sutras, it is important to note that for Indians, theories and philosophies were not purely of academic interest. They were applied in many practical sciences. For example, practice and treatment in Ayurvedic medicine is extensively and elaborately based on Nyaya and other systems of Indian philosophies.

Ancient Greek's Scientific Methodology: In ancient Egypt and Mesopotamia, anything that happened was explained as the work of "hidden hands." Different phenomena were explained as the work of different gods. Diseases were viewed as caused by demons. Inspite of the fact that Thales foretold the Solar Eclipse we cannot say that the scientific method was developed in 600 BC. Some of the first attempts to replace the doctrine of the "hidden hands" by practical modes of explanation were made by Greek philosophers around the sixth century BC. They attempted to explain natural phenomena in terms of the physical observations. They endeavoured to introduce *logos* or reason in to the world around them. Their approach became an admixture of scientific, religious and philosophical reasoning. The Greek genius was deductive rather than inductive and was therefore at home in mathematics and geometry. They were good observers and hence helped in the advancement of astronomy. Eratosthenes, the geographer, estimated the circumference of the earth as 250,000 stadia (about 24,500 miles). The true circumference* is 24,900 miles. The most outstanding among the Greek scientists was Archimedes (287-212 BC) who wrote the book on *Floating Bodies*.

**Science Past and Present*, F.S. Taylor, p. 45.

During the middle ages, no significant development in scientific methodology took place.

Scientific Method (13th century to 18th century)

In the west, the scientific method was first enunciated by *Roger Bacon* (born about 1210 AD.). He felt the need for experimental methods. He seems to have come very near to being an experimental scientist of the modern type. He declared that the only way to verify or disprove any statement was '*to experiment and observe*'. He had a laboratory at Oxford and studied lenses and mirrors with great care. There are indications that he had a telescope. He systematically studied reflection, refraction, rainbow, burning glasses and magic mirrors. In 1248, he announced the composition of gunpowder. He also invented some mechanical contrivances and predicted others, such as self-propelled ships and flying machines (where a man sitting in the machine revolves an engine by which skillfully madewings beat the air like a flying bird).

In AD 1543, two books were published: *De Humani Corporis Fabrica* of Andreas Vesalius and *De Revolutionibus Orbium Coelestium* of Nicholas Copernicus. These books have become classics in the history of science. Both of these books initiated events that revolutionized science.

Francis Bacon (1561-1626) regarded science as neither a luxury nor something to acquire fame or produce miracles with, but to improve, the condition of human existence. Bacon's view of scientific method was essentially experimental, qualitative and inductive. However, he distrusted mathematics and the art of deductive logic that went with it. He regarded the collection of a large body of facts as a prime requisite of an experimental method. Then any subject could be investigated by classifying facts relating to that topic. The scientific method outlined by him consisted of the following steps:

(i) A list of 'positive instances' of the phenomenon in question should be drawn up (i.e. instances where the phenomenon was present). e.g. in studying the nature of heat, positive instance would be the sun's rays, flames etc.

(ii) A list of negative instances of the phenomenon should be drawn up. e.g. Heat was not present in the moon's ray's, air, water, etc.

(iii) 'Degrees of comparison' should be noted. e.g. The variation of animal heat with excercise, or frictional heat with the vigour of the motion that produced it.

In view of these steps, scientific knowledge could be obtained by trying out various hypotheses, excluding the improbable ones and further the more likely ones. During this exercise, other instances might be used to discriminate between rival hypotheses.

Rene Descartes (1596-1650), a renowned philosopher, in his *Discourse on Method* published in 1637, explained four basic principles of scientific method:

(i) Never to accept anything as true which one did not clearly know to be such, avoiding precipitancy and prejudice, and comprising nothing more in one's judgement than was absolutely clear and distinct in one's mind.

(ii) To divide each of the difficulties under examination into as many parts as possible.

(iii) To proceed always from the simplest and easiest to the more complex, assigning in thought a certain order even to those objects which in their own nature do not stand in relation of antecendence and sequence, i.e. to seek relationship everywhere.

(iv) To make enumerations so complete and reviews so general as to be assured that nothing was omitted.

MODERN SCIENTIFIC METHOD

Ever since science began to evolve into its modern form, beginning with the 16th century, most of the scientific discoveries have followed a pattern that has come to be known as the *scientific method*. Prof. Narlikar of TIFR, India has regarded it to consist of: the experiment (E), the observations (O), and the deduction (D). This E·O·D process operates in most scientific investigations. Scientific method cannot be strictly defined, for it is a varying process which develops with time. There may be variations in the steps to be followed in the use of a scientific method but the following are representative:

1. Recognition of the Problem
2. Experimentation
3. Observation of Facts and their Grouping

4. Formulation of Hypothesis
5. Verification of Hypothesis and Formulation of Theory

Recognition of the Problem

Here one exactly puts down the problem to be studied and solved. One thinks of the various aspects of the problem and sees what arouses one's curiosity about the problem. The proper awareness and clear recognition of a specific problem or situation may be stimulated or originated (1) by mere general curiosity (2) by an actual need for the solution of the problem or (3) by reading or rethinking about a similar problem. Indeed, several famous discoveries are reputed to have been stimulated by such things as being hit by a falling apple, by daydreaming while watching bubbles rise in a glass, and by a dream (when unconscious mind contains some unsolved problem).

Most, however, are the results of hard work. No problem can be solved satisfactorily until there is a clear and accurate mental picture of what is to be solved. The problem should be approached with an open, unprejudiced mind with as much objectivity and detachment as possible. Misplaced enthusiasms and bias must be reduced to a minimum, if not completely eliminated.

Experimentation

This step includes preliminary studies of available pertinent informations to ascertain what is already known about the problem or condition being investigated. This includes reading, preliminary investigations, gathering suggestive informations from reliable sources and persons. In view of the collected informations and various aspects of the problem to be investigated, different experiments are repeatedly performed.

Observation of Facts and their Grouping

From the above experiments, qualitative and quantitative observations are made. For example, an agricultural scientist observes the growth in plants after the addition of a particular fertilizer. He also observes, how much growth is caused by a particular fertilizer compared to another. A medical scientist observes the effects of a particular drug and further how much effective a drug is compared to another. Thus the scientist has a collection of facts (truth capable of experimental verification). Among these facts there may be some which do not have any bearing on the problem, one should reject such and group all the remaining ones. Those grouped are then classified according to the different aspects of the problem. Statistical methods of data analysis are used sometime for grouping of facts.

Formulation of Hypothesis

From the grouped or classified facts, obtained in the second step, one should draw all those conclusions which appear to be true. These conclusions taken together is sometimes called a working hypothesis (because we work forward from it). This hypothesis might be considered as a speculation or assumption, as yet unproved and tentative or suggested conclusion or explanation of the problem. A hypothesis may be the suggestion of a cause that may produce effect, although it is not yet proved. Many people, before Newton saw apples falling but none could link the cause with the effect. Newton pondered on the reason for the apple falling from the tree to the ground and arrived at the working hypothesis: *Earth attracts all particles towards it*. This ultimately led to the Newton's famous Gravitational Law. Sometimes from the classified facts, either one hypothesis or many for a given problem can be suggested, depending on its nature.

No conclusion, however insignificant at the moment, should be ignored. A hypothesis may be formed in two ways: (i) Deduction, and (ii) Induction.

(i) *Deduction*: This method is classical and was propounded by Aristotle. Scientifically, the method has become outdated. In this one guesses (keeping a view on his observations) a general statement (hypothesis) and deduces a number of statement from it. If each deduced statement is found correct experimentally, it lends support to the hypothesis, otherwise exposes its limitations. The hypothesis is then modified.

(ii) *Induction:* This method was initiated by Roger Bacon. In this method we go from some to all, from less general to more general. It is a process of making generalizations on the basis of particular facts. After making a lot of particular observations by repeated experimentation, a set of conclusions (each capable of experimental verification) is drawn. This set of conclusions are combined into a general statement. The hypothersis is said to be formed on Inductive reasoning. As there are less chances of the hypothesis being wrong in Induction than in Deduction, so the process of Induction is regarded as better and more scientific.

Verification of Hypothesis and Formulation of Theory

A hypothesis may be tested (i) through additional accurate observations and investigation, (ii) through controlled scientific experiments, if such can be performed for the problem under study or (iii) by combination of (i) and (ii).

The hypothesis is verified statementwise. One picks up a statement and devises experiments for its verifications. For this one has to investigate and make additional observations. If the chosen statement is thus verified experimentally, it is given the status of a law otherwise rejected. The laws so obtained are put together and a theory is said to be formed.

In view of the discoveries of scientific method and that of atom-bomb, Dalton's Atomic Theory has lost its original status and it may now be called Dalton's Atomic Hypothesis.

Above break-up of the scientific method does not mean that a working scientist consciously follows these steps. He does not set one day aside for recognition of the problem, a second day for experiment, a third for observation, a fourth for generalization and the fifth for verification. Sometimes, all the five processes go on nearly simultaneously and quite unconsciously. During collection of data, a possible hypothesis may suggest itself as a hunch and almost immediately one may become aware that it has already been tested earlier by experiments designed for some other purpose. Often different persons perform each of the steps. The scientific method as described above is merely a formalized expression of a process that a scientist consciously or unconsciously adopts as he works. A scientific theory or law is acceptable only so long as it fulfils the criterion that it explains—or at least does not conflict with—any phenomenon observed in Nature. Once it fails to satisfy this criterion, it must be modified or totally rejected.

Example 1

Robert Boyle (1627-1691) studied chemistry in a scientific spirit. He wanted to know the relation between the volume and pressure of a gas at a constant temperature. He took a certain mass of a gas and subjected it to increased pressures (keeping temperature fixed), each time he found its volume decreased. From the quantitative study of his experiments, he formed a working hypothesis—*Temperature remaining constant, the volume of a given mass of a gas is inversely proportional to the pressure.* He found the constant of proportionately K = P × V. Then he verified the hypothesis experimentally by taking another mass of a gas and subjecting it to different pressures and noting the corresponding volumes. The hypothesis became a law, now well known as Boyle's Law.

Example 2

Alexander Fleming (1929) might have followed steps somewhat similar to the following in the discovery of the famous antibiotic, *penicillin*. He observed that on the surface of one of the dishes containing culture of staphylococci, had developed a growth of mould. It seemed like the mould on several other dishes, except that all around the edges of the fungus, the colonies of staphylococci had been dissolved. Instead of being an opaque mass, a yellow clump of bacteria, they had lost their colour; they look like drops of dew. Fleming might have quickly sterilized the culture and stopped but characteristically curious, he hypothesized that this mould produced something which might cause the death (or at least prevent rapid growth) of the bacteria and hence be useful in the treatment of bacterial diseases. But this much observation would not prove his hypothesis. The lack of bacterial growth around the mold might have some other cause, or be merely coincidence. Fleming experimentally tested his hypothesis by repeated experiments with plate cultures of the same bacteria and he introduced the same mould to observe if the phenomena occurred repeatedly. After recording his data, he organised and interpreted his experimental results and concluded that this mould did produced some antibacterial substance. Later work by Fleming, Florey and many other scientists proved many details of the phenomenon and this eventually led to the production of the famous antibiotic penicillin. It was produced in its purified form in 1940.

Example 3

Torricelli observed that water in a pump, rises to a height of 34 feet and no more. He thought of it for a long time and tried to find out the reason. After recognising the problem, he formed a working hypothesis—*the rise of water in a pump to a height of 34 feet, is due to the pressure exerted by the atmosphere.* He deduced from the working hypothesis that mercury should rise to a height of 30 inches.

$$\begin{aligned} gdh &= \text{pressures} = gd'h' \\ g\times1\times34\times12 &= g\times13{\cdot}6\times h' \\ h' &= \frac{34\times12}{13{\cdot}6} = 30 \text{ inches} \end{aligned}$$

When he actually performed the experiment with mercury, he found that mercury rose to a height of 30 inches. This verified his hypothesis.

Example 4

The rejection of Phlogiston Theory (for explaining combustion) which held the field for a long time, was due to the development of scientific method. According to Phlogiston Theory, when a metal burns, something described as *Phlogiston* escapes and the residual material was described as *calx*.

$$\text{Metal} \xrightarrow{\text{on burning}} \text{calx} + \text{phlogiston}\uparrow$$

But when scientific method was applied by Cavendish and Lavoisier, it was quantitatively found that residual material had more weight than the original metal. Thus the Phlogiston Theory was set aside. The correct explanation is a follows:

$$\text{Metal} \xrightarrow{\text{on burning}} \text{Metallic Oxide}$$

$$\text{e.g. } 2\,Mg + \underset{\text{(from air)}}{O_2} \xrightarrow{\text{on burning}} 2\,MgO$$

5

Some Eminent Indian Scientists

Sir Jagdish Chandra Bose (1858-1937)

Jagdish Chandra Bose was born on November 30, 1858 at Rarikhal in Mymensingh district of East Bengal (now in Bangladesh). His father, Bhagwan Chandra Bose, was a Deputy Magistrate. J.C. Bose got his early education in his village. In 1871, he was admitted to St. Xavier School, Calcutta. During his boyhood he read the Bengali translation of the *Ramayana* and the *Mahabharata* and was deeply impressed with the stories of heroism and sacrifice described in these two great epics. Besides studies, he took part in gymnastics and boxing. As a child, he was fond of collecting all kinds of insects, trapping fish and capturing even water snakes. As a grown-up student of St. Xavier's College, Calcutta, he used to spend all his spare cash on animal pets, and all his spare time on their care. In those days Calcutta University did not offer Zoology. Instead, Physics was a popular subject because of the teaching of Father Lafont, the famous professor of Physics at St. Xavier's College. Due to these factors, Bose took Physics. Father E. Lafont, instilled in him a love for experimental physical science, and this was further nurtured under the influence of Lord Raleigh.

J.C. Bose obtained his B.A. degree with science as special subject, in 1877 from Calcutta University. In 1881, he went to England for higher studies. He obtained the Natural Science Tripos of Cambridge University and B.Sc. of London University. Bose returned to India in 1885, and joined the Presidency College, Calcutta, as a Professor of Physics. The pay-scale offered to him was humiliatingly low and the research facilities were lacking. In spite of this, he was determined to struggle for scientific achievement.

Jagdish Chandra Bose is famous for his experiments in Physics on electric waves, and in Botany on life in plants. He is known for his attempts in establishing the relationship between the living and non-living things.

SIR J.C. BOSE FRS (1920)

SRINIVASA RAMANUJAN FRS (1918)

Dr. R. RAMANNA, Director BARC

PROF. MEGHNAD SAHA FRS (1927)

C. V. RAMAN, Nobel Laureate 1930

Padam Bhushan H.J. BHABHA FRS (1941)

PROF. D.S. KOTARI, Former Chairman UGC

PROF. J.V. NARLIKAR

SIR P.C. RAY FRS (1919)

Padam Vibhushan S.S. BHATNAGAR FRS (1943)

PROF. P. MAHESHWARI FRS (1965)

PROF. BIRBAL SAHNI FRS (1936)

Padam Bhusan T.R. SESHADRI

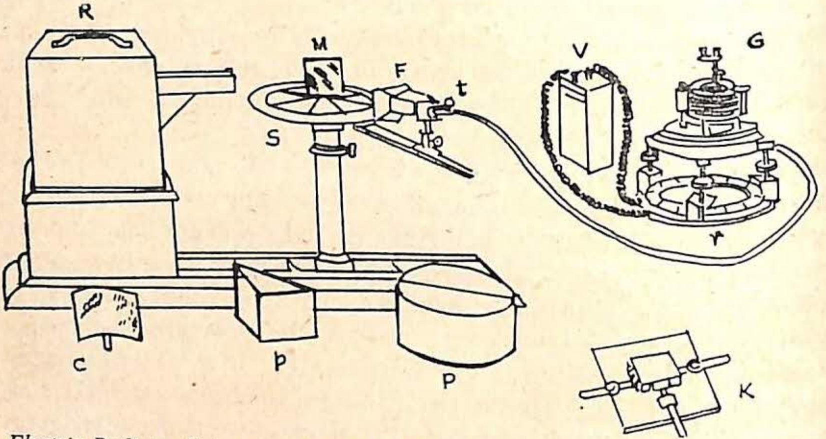
Padam Bhusan M.S. SAWAMINATHAM FRS (1973)

Padam ATMA RAM, Former Director CSIR

Scientific research on electric waves was initiated by Bose in the early nineties of the 19th century. He was investigating the nature of spark discharge from an induction coil and its effect on the surrounding medium. Clarke Maxwell had predicted (on purely theoretical grounds) twenty years before that light waves are of electromagnetic nature. This was verified by Hertz in 1880. In 1887, Hertz discovered that electrical discharges from a machine produce waves in space somewhat analogous to light waves. The shortest electromagnetic wave obtained by Hertz was of wavelength 5 metres. Marconi, Lodge etc. also used electric waves of such large wavelengths. Professor Bose devised his own instrument—Electric Radiator, and succeeded in generating waves having smaller wavelengths—5 millimetre. He thereby advanced quantitatively, Hertz's study. Bose and Hertz showed that short electromagnetic waves behave exactly as a beam of light, both being amenable to reflection and refraction. Bose even managed to 'polarise' the electromagnetic waves. His another investigation related to the study of the rotation of the plane of polarization. He discovered a special crystal, 'nemalite' and showed that it polarised electric waves just as a light-beam is polarised by tourmaline (a crystal). His first scientific publication entitled 'On Polarisation of Electric Waves by Double Refracting Crystals' appeared in the May 1895 issue of the *Journal of the Asiatic Society of Bengal*.

Independently of Marconi and Lodge, Bose had clearly foreseen the application of the electric waves of his experiments to wireless telegraphy (telegraphy without wires). In 1895, he demonstrated before the Governor of Bengal and the public how electric waves could travel from his radiator in the lecture room to another 23 metres away, where his receiver managed to pick up enough energy to ring a bell and fire a pistol. He later increased the distance by 1.6 km in the same experiment.

Professor Bose went, on the invitation of the British Association, to attend its Liverpool session to demonstrate his experiments. It was a grand success. Bose's paper outlining his researches on electric waves so impressed Lord Kelvin that he not only broke into the warmest praise, but limped upstairs to the ladies' gallery and shook Mrs. Bose by both hands with glowing congratulations on her husband's brilliant work. The Liverpool success brought an invitation to deliver a series of Friday Evening Discourses at the Royal Institution. It made the India Office authorities, to realize



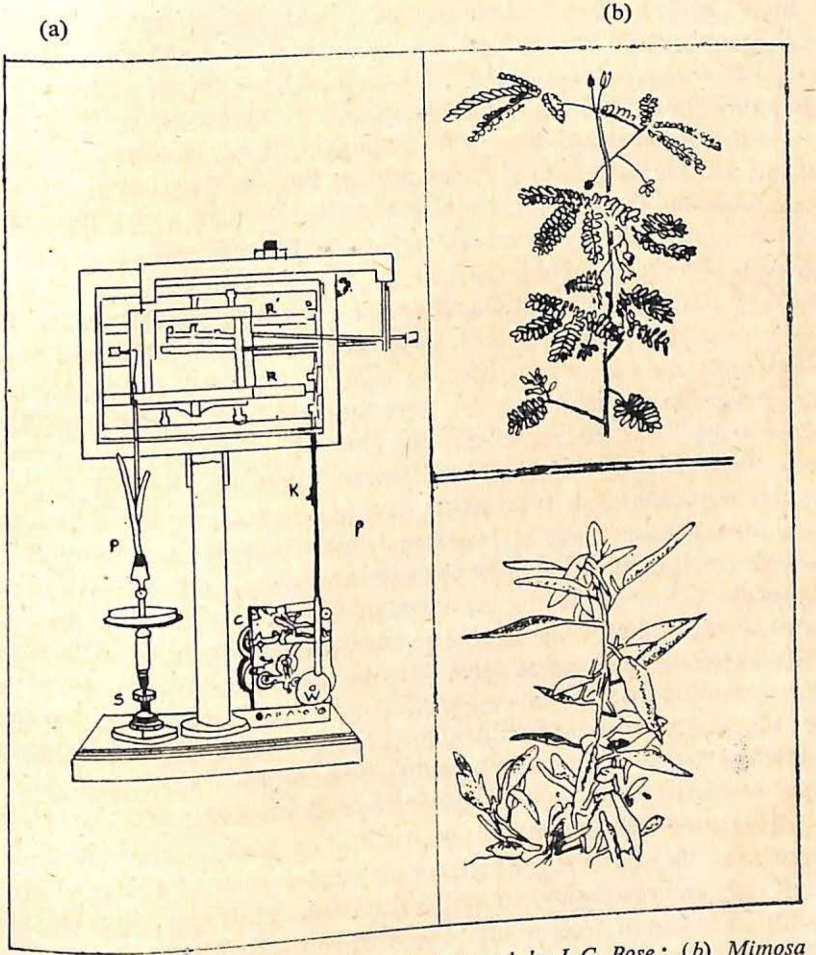
Electric Radiator designed and used by J. C. Bose. R, radiator; S, spectrometer; M, plane mirror; F, funnel; C, cylindrical mirror; P, total reflecting prism; P semi-cylinders; t, tangent screw by which the receiver is rotated; r, circular rheostat; G, galvanometer; K, crystal holder; and v, volatic cell.

the genius in J.C. Bose and they immediately granted him three month's extra deputation leave for preparation and delivery of the lectures.

Father Lafont mentioned that Bose's discover preceded that of Marconi; in contrast to the latter, Bose did not take any patent as he thought that result of any scientific discovery should be public property. On his ascetic trait, the leading British technical journal, *The Electric Engineer*, expressed surprise "that no secret was at any time made as to its construction (signalling device), so that it has been left open to all the world to adopt it for practical and possibly money-making purposes". Sister Nivedita and Mrs. Ole Bull of the Ramakrishna Mission were his admirers. They took patents (for Bose's self recovering detector of electric rays) on his behalf in U.K. and U.S.A., but Bose never used the rights and allowed the patents to lapse.

J.C. Bose served the Calcutta University as Professor of Physics from 1885 to 1915. In 1896, he got the D.Sc. degree from Cambridge University.

Once, J.C. Bose noted that the peculiar behaviour of his electric-wave receiver or "coherer". It seemed to show signs of "fatigue" after continuous use, but could be 'revived' to its original sensiti-



(*a*) *The High Magnification Crescograph designed by J. C. Bose* : (*b*) *Mimosa pudica;* and (*c*) Desmodium plant.

vity after some "rest". Such instances, together with his inborn interest in biology, diverted him to the investigation of responses in the living and non-living to various external stimuli. In 1900, he read a paper, 'On the similarity in Responses in Inorganic and Living Matter', at the International Congress in Physics at Paris and later at the British Association for Advancement of Science, Bradford.

Bose's observations and his use of words like 'fatigue', 'sleep', exaltation', 'rest', 'irritability' etc., in respect of inert and vegetative matter, met with criticism. He worked hard during 1899—1904. He published eight papers and completed a monograph: *Response in the living and non-living*. He found that the curve of the fatigue of an instrument closely resembled the fatigue curve of an animal tissue. In fact, Bose thought that his new view, life pulsating in all matter from rocks and reefs to reeds and rams would integrate the fragmented sciences.

Bose's descent into life sciences and plant physiology in particular, was really a revival of his old (since his childhood) and deep-rooted interest in animal life. In fact, he studied medicine for some time in England and also kept contacts with Prof. Vines, the famous botanist. His investigations showed that not only animals but also vegetable tissues under different kinds of external stimuli (such as mechanical, application of heat, electric shock, chemical) produce similar electric responses. He invented 'crescograph' in which the imperceptibly slow growth of plant could be magnified several million times and accurately recorded. In 1914, he demonstrated his findings, before the members of the British Royal Society. His 'resonant recorder' registered the speed of transmission of excitatory impulse; the 'oscillating recorder' traced the throbbing pulsations of the telegraph plant and finally the 'death-recorder' indicated the death-throes of the plant. In recognition of his outstanding work, Bose was elected a Fellow of the Royal Society in 1920.

Bose's pioneering research activities and lecture tours in U.K. and the continent brought not only unprecedented fame to him but also an era of glory to his motherland. This has been beautifully narrated in several letters written by Swami Vivekananda and Tagore.

Professor Bose retired as Senior Professor of Physics in 1915 but continued to be associated with Presidency college as Emeritus Professor for two years. In the meantime he raised money from the public for establishing a research institution. He inaugurated the new research institute, on November 30, 1917. This institute according to him was "not merely a laboratory but a temple". As a matter of fact, the institute is called '*Basu Vijnan Mandir*'—a temple of science. In his dedicatory address at the inaugural ceremony of the institute, Bose said, "the advancement of science is the principal object of the Institute, and also diffusion of knowledge". He then expressed the desire "that so far as the limited accommodation permits, the facilities of the Institute should be available to workers from all countries. In this I am attempting to carry out the traditions of my country which, so far back as 25 centuries ago, welcomed all scholars from different parts of the world within the precincts of the ancient seats of learning of Nalanda and Taxila".

On November 24, 1937, Bose died of heart attack. In 1945, a biographical note on him appeared in the *Encyclopaedia Britannica.* It mentioned that his biophysical research was "so much in advance of his time that its precise evaluation was not possible".

Srinivasa Ramanujan (1887-1920)

Srinivasa Ramanujan was born on December 22, 1887 at Kumbakonam, Tamil Nadu. He belonged to a poor but renowned family. Ramanujan displayed prodigious talent with numbers, equations and geometrical problems even before he reached high school. He passed the high school examination in 1903. After matriculation, the neglect of English resulted in his failure in the Intermediate examination. Consequently the Subrahmanyam scholarship that he had won earlier, was discontinued. He had to abandon his studies for he was too poor to afford an university education without a scholarship. In 1907, he tried again but failed.

After his failure in the Intermediate examination, Ramanujan tried hard to get a job but in vain. His father got annoyed when he saw the son immersed all the time in mathematical problems. He ridiculed the boy for wasting time "scribbling useless calculations and theories that in no way earned him a living." Fearing that the son might get mad in pursuing mathematics, he got Ramanujan married in 1909. Ramanujan's friends realized his acute financial problems and got him a clerical job in the Madras Port Trust.

Sir Francis Spring (Ramanujan's employer), a mathematician of distinction himself, took special interest in Ramanujan's mathematical pursuits. He quietly sent some of the problems worked out by Ramanujan to the eminent Cambridge mathematician Professor G.H. Hardy. Prof. Hardy found Ramanujan's work of profound significance and at once decided to get him to Cambridge University. He arranged a scholarship for Ramanujan. In 1914, Ramanujan became an honoured student at Cambridge. His uncanny memory and his ability to solve intricate mathematical problems impressed everyone.

Ramanujan's health did not allow him to stay at Cambridge for more than five years. But even in so short a period, he published 21 most outstanding papers of amazing originality. Vinogradow, Stalin Prize winner using methods traceable mainly to the work of Ramanujan and his collaborators, has been able to show that every large integer can be expressed as the sum of at most four primes. In 1917, Ramanujan developed a formula for the partition of any natural number by a series of successive approximations. The famous Waring problem (expressing an integer as the sum of squares, cubes or higher powers of a few integers) remained unsolved for a century until Ramanujan and his collaborators invented the analytical method for tackling the problem.

The Royal Society went out of its way and made him a Fellow (FRS) in 1918. The same year, he was made a Fellow of the Trinity College, Cambridge University.

Ramanujan worked on Riemann's Zeta function, moch-theta function, modular equations, identities, theories of continued fractions and elliptic functions. He desired that the mathematics he created would remain clean and pure from any contact with technological applications. In fact, the very idea that science has a social function to perform, had not arisen by that time. Ramanjan's and others work on Riemann's Zeta function has now been used in technology. It has been applied to the investigation of the temperature of furnaces aimed at building blast furnaces.

Ramanujan's researches made him a pure mathematician of highest order. Julian Huxley has hailed him as the greatest mathematician of the century; the eminent mathematician J.R. Newman regarded the genius of Ramanujan as supreme. Prof. G.H. Hardy wrote: "I still say to myself when I am depressed and find myself forced to listen to pompous and tiresome people, 'Well, I have done one thing, *You* could never have done' and that is to have collaborated with both Littlewood and Ramanujan on something like equal terms."

Overwork at Cambridge shattered Ramanujan's health. He was hospitalised with acute tuberculosis of lungs. A return to the warm climate of India was advised. Prof. Hardy regretted this very much: "I owe, more to Ramanujan than to anyone else in the world and any association with him is the one romantic incident of my life."

Return to India in 1919, brought no relief to the ailing Ramanujan. Despite the best medical care, he succumbed to tuberculosis on April 26, 1920. To India and the world, Ramanujan bequethed his notebooks in which he jotted down his calculations and theorems—a mine of mathematical knowledge for generations to come.

Meghnad Saha (The Nuclear Scientist in the First Lok Sabha)

Meghnad Saha, born in 1893. was one of the eight children of a poor shopkeeper in village Seoratali, 45 km from Dacca. At an early stage of schooling, his father due to financial difficulties made him return to groceries. Only after the intervention of some primary school teachers and his elder brother having eventually found a job, was Saha able to return to his studies. Saha was thus a man who grew out of a poor, rustic and backward environment to take a leading place in Indian science. "Saha declared himself against foreign control of India when he was 12, and continued to do so throughout his life. His plans were predicated upon a complete structural alteration of social relationships and political institutions," says R.S. Anderson, in his book: *Building Scientific Institutions in India*. Saha earned the M.A. degree from Calcutta University. He received early inspiration from his teachers, Acharya J.C. Bose and Acharya P.C. Ray. He was an indefatigable worker. Saha's first research trip abroad (from 1919 to 1921) came after he was awarded the D.Sc. by Calcutta Unlversity. He worked with a group at Imperial College, London. In 1920, Saha stayed for a year in Germany and it was during this period that he began acquaintance with Einstein, Planck, Sommerfeld and a host of other leading European physicists of his time and with whom he sustained contacts all his life.

Saha recalled the progressive dissociation of substances with continued heating—the substance turning into a gas, the gas molecules decomposing into those of simpler compounds, the latter again into those of the constitutent elements, until finally the elements are decomposed into atoms. He postulated that further heating would disrupt the atoms themselves into ions and unattached electrons. The heat energy would now begin to derive some of the outer electrons from their "atomic dwellings" into the "no atom's land" between the atoms. This process of atomic *truncation*, with loss of satellite electrons is called *Ionisation* and the truncated atom an *Ion*. Saha asserted that at the very high temperatures (of the order of 6000°C or more), prevailing in stellar atmospheres, many of the constituent atoms of a star must be truncated with many of their electrons torn off. Thus, stellar atmospheres were merely gaseous mixtures of freed electrons and atoms both truncated and whole. The spectroscopic evidence of this phenomenon has been obtained.

He applied statistical reasoning of the kinetic theory and the laws of thermodynamics to a gaseous mixuture of free electrons, ions and atoms and arrived at the conclusion : For atoms of any given element, truncation or ionisation was promoted not only by high temperatures but also by low pressures. He mathematised these ideas in the form of an equation, enabling calculation of the degree of ionisation in a stellar atomsphere, given its pressure, temperature and the energy required to detach the atoms each of its successive electrons. Epoch-making Saha's equation relation to stellar spectra has been aptly termed as "one of India's most precious gifts to world seience". Saha's equation, modified later by Fowler, Milne and others, is merely an elaboration of the original ideas of Saha. His ionisation theory has several applications such as transmission of radio waves, conduction of flames, formation of arcs and explosive reactions. Saha, in later years of his life, worked on the propagation of radio waves through the ionised upper atmosphere.

Saha, though a nuclear physicist, was not much in favour of atomic energy because that source of power would not increase self-reliance significantly. Saha saw hydroelectricity as the big power source in India.

Like J. B. S. Haldane, J. D. Bernal, Joliot Curie and he (Saha) emphasised upon the social function of science. In 1938, Prof. Saha perceived the dire necessity of economic planning for national rejuvenation and the paramount role of science in such a scheme. He deserves great credit for having said at that time: "If we desire to fight successfully the scourge of poverty and want from which 90% of our countrymen are suffering, and to lay the foundation of a strong and progressive life, we must make the fullest use of the power which a knowledge of Nature has given us".

Saha's concept of national planning on the basis of scientific approach, and his vision of expanding facilities for scientific and technological research were readily appreciated by Netaji Subhas Chandra Bose and Pandit Jawaharlal Nehru. Since the dawn of Independence in 1947, Pandit Nehru, India's first Prime Minister, subsequently expanded the educational and research facilities, and simultoneously initiated formulation and execution of national planning through five-year plans. This has been possible largely due to the inspiration received from Saha and the able assistance from other Indian scientists like S.S. Bhatnagar, D.S. Kothri etc.

Saha wanted utmost efforts to be made to be dependent only on indigenous technology. He devoted a chunk of his energies to the problems of education, national planning, river valley projects, and agricultutal co-operatives. Almost every month, he used to write on one or the other of such subjects, in the journal '*Science and Culture*,' which he edited for four years. He used to lash out furiously at those native industrialists who gobbled up enormous profits and at foreign capitalists in control of jute, tea, coal and other industries who took away huge amounts of our wealth.

It was Saha's acute concern for socio-economic upliftment of the country which led him to politics. It was also due to the inadequate funds that used to be sanctioned for his research projects. By this time, he had become an established national figure. He contested the election to the First Lok Sabha, in 1951, as an independent candidate. He refused to accept a party ticket in order to guard his integrity. He was elected by a large majority. As a member of the Lok Sabha, he fought for causes dear to him, mainly for the development of heavy industries in India. Unfortunately, he died in 1956 when the second five-year plan (which embodied many of his ideas) was on the verge of inauguration.

Nobel Laureate C. V. Raman (1888-1970)

Chandrasekhar Venkat Raman was born on November 7, 1888, at Tiruchirapalli in South India. He belonged to a Hindu Brahmin family. His father Chandrasekhar Aiyar was initially a school teacher and later, Professor of Physics at the Vizagapatnam College. C.V. Raman was a born genius. At the age of 12, he passed the entrance examination of Madras University with distinction. There is an interesting incident about his entry into the College. He was asked by one of the lecturers, "Whom do you want?" "No one, sir", he replied. The lecturer ordered him to go out of the college boundary because college campus was not a place for school boys. In fact Raman was so young that the lecturer regarded him a wandering school boy.

Raman was educated in the Presidency College, Madras. At the age of 16, he did his B.Sc. standing first in the University. He stood first in M.A. Mathematics also. Then he thought of going to England for higher studies. He felt, he would not be able to bear the severe cold of England and so he dropped the idea. While he was a college student, he contributed a few original papers in Physics which were published in the 'Philosophical Magazine' of England. Besides his interest in science and experiments, he was so keenly interested in Sanskrit literature that he read the original versions of the great epics, the *Ramayana* and the *Mahabharata*. When he was young, C.V. Raman was captivated by the different sounds of musical instruments. He would combine his scientific interest with of 'artistic pleasure' by studying the theory musical instruments like *veena*, violin, pianoforte, cello and *mridangam*. In the beginning of the twentieth century, nobody in India dared to adopt scientific research as a wholetime career. So, like other bright students of the day, he decided to join Government service. He sat for Indian Audit and Accounts Service Examination and topped the list of successful candidates. Thereafter, he was appointed Assistant Accountant General in the Imperial Government Service, In 1907, he was transfered to Calcutta and there he got an opportunity to carry out his research work in Physics at the 'Indian Association of Science' founded by Dr. Amritlal Sirkar.

The Vice-Chancellor of Calcutta University, Sir Ashutosh Mukherjee, impressed by Raman's research work, offered him Palit Professorship of Physics at the University College of Science, Calcutta. He readily accepted the offer in 1917. He carried on his academic work at Calcutta University till 1933. Within a short period, he distinguished himself in research work and the University of Calcutta conferred D.Sc. on him in 1921. He was elected a Fellow of the Royal Society in 1924. He was soon recognized as one of the world renowned physicists.

The study of colour had a great attraction for C.V. Raman. Once in 1921, he was on a voyage to Europe. He was completely fascinated by the deep blue of the Mediterranean waters. The unearthly beauty of the ice-blue of the Swiss glaciers made a similar impression on his mind. When he came back to India, he experimented on the diffusion of light, when passed through clear water, transparent blocks of ice and other materials. From the observations it was clear that light gets diffused through all transparent bodies, but the degree of diffusion and the state of polarisation differ from one material to another.

Though Albert Einstein was the first to suggest that a beam of light could also act as a fusillade of minute bullets, yet it was the work of Raman that made this idea acceptable to scientists. After Compton's discovery of the Compton Effect, Heisenberg, in 1925, predicted that a similar effect ought to be found in the case of visible light. But Raman had come to the same conclusion before Heisenberg had made his prediction even before Compton's work. In 1928, Raman definitely showed that scattered light had weak components of changed wavelengths. Furthermore, the exact wavelengths produced in the scattering depended on the nature of the molecules doing the the scattering. The discovery of *Raman Effect* and *Raman Spectra* proved to be most useful in determining some of the fine details of molecular structure.

For his experiments, instead of sunlight, he used monochromatic (of one colour) radiations from mercury-arc lamp. When a beam of one colour, say the green light of a mercury lamp, passes through a transparent medium such as benzene, one of the following two things may happen to each one of the numerous light bullets or photons of which the light beam consists:

(i) It may pass through the invisible inter-molecular gaps of the liquid without a close encounter with any molecule of benzene, thus keeping its initial energy intact on emergence.

(ii) Alternatively, it may collide headlong with a molecule of benzene.

When a photon meets a molecule, it may emerge with some loss (or gain) of energy which it imparts to (or abstracts from) the molecule. As a result, the energy contents of emergent photon is weakened or strengthened, the deficit (or excess) being absorbed (or surrendered) by the molecule. In the rainbow colours from violet to red, the energy content of the photons continuously diminishes. Now, if the molecular encounter diminishes the energy of a photon, the loss of energy shows itself in a shift of colour of the photon towards the red of the spectrum.

The Raman Effect is important due to the fact that the associated colour shift in an incidental beam of light is a measure of the energy lost by the incoming photons. Since this loss is equal to the energy gained by the molecules of the medium so it provides a measure of the increase of internal energy gained by the molecules and the atoms of the substance. Thus it helps in inferring the details of molecular and atomic structure of the medium. In other words, Raman gave a technique of exploring the interiors of molecules and atoms. Raman Effect proved to be an invaluable aid in understanding the physical behaviour of the liquid and crystalline states of the matter.

Raman was President of Indian Science Congress (1928). In 1929, C.V. Raman was knighted by the British Government and in 1930, he won the Nobel Prize in Physics for his discovery. He was the first Asian scientist to win the Nobel Prize. At the presentation ceremony in Stockholm, he demonstrated the influence of the Raman Effect on different liquids including alcohol. After the ceremony, at a reception in his honour, one of the scientists remarked that they had been delighted to see the influence of the Raman Effect on alcohol earlier and that they would like to see the effect of alcohol on Raman. Raman politely refused to touch the alcoholic drinks that were served at the dinner. In 1930, he made an extensive tour of Europe and America at the invitation of several scientific organizations.

In 1933, Raman was appointed as the Director of the Indian Institute of Science at Bangalore. Till 1943, he worked, besides other things, on the theory of musical instruments particularly on the *Tambura*, the well-known Indian musical instrument. Realizing the need for science research institutes in India he founded in 1943, the Raman Research Institute in Bangalore for which he himself became the Director. In 1948, he became National Professor. In 1954, he was awarded the *Bharat Ratna*, the highest honour in India. Raman represented India at many international science organizations such as the Zurich Physical Society and the Soviet Academy of Sciences. He won the International Lenin Prize in 1957.

Among the numerous publications that flowed from Raman's research work, are Molecular Diffraction of Light, Mechanical Theory of Bowed Strings, Diffraction of X-rays, Theory of Musical Instruments and Physics of Crystals.

This eminent physicist was greatly interested in synthetic diamonds, because he thought, diamond to be the ideal substance for study of the solid state of matter, by means of Raman Spectrum. The ideas and results, which have emerged from his light diffusion studies have found tremendous applications in the study of X-rays Raman took active part in experimental science till the end of his life in 1970.

Raman possessed the boundless curiosity of a little boy to know new things and the intuition of a great genius in understanding the secrets of Nature. The life of this great scientist was truly the life of a great seer.

Homi Jehangir Bhabha (1910-1966)

Homi Jehangir Bhabha was born on October 30, 1909. He was brought up in a rich and aristocratic family of Bombay. He grew up amidst books, music and paintings. He attended schools with European children and met and heard leading nationalist politicians at his own aunt's place. He saw the relationship that existed between these leaders and the industrialists of India. Bhabha had his early education in the Elphinston College and the Institute of Science in Bombay. In 1930, he took his B.A. degree in Mechanical Sciences Tripos of Cambridge University.

H.J. Bhabha, like other young men of his age and background, took off for higher studies in England. Between 1932-34, he got a fellowship at Cambridge University. He was awarded Ph.D., in 1934, by Cambridge. During these years of his European interlude, he had an opportunity to mix with some of the best scientific groups in Europe. He worked in the extremely active Institute at Copenhagen which housed Neils Bohr's group. He also worked with the world renowned scientist Fermi, who was instrumental in establishing an atomic centre at Chicago.

Bhabha's contribution to the field of atomic physics is significant. To comprehend Bhabha's contribution to the study of cosmic rays, it is necessary to know what cosmic rays are. Primary cosmic rays are fast-moving, ultra-energetic, sub-microscopic particles like the nuclei of hydrogen atom. When some of these rays approach the earth and enter our atmosphere, they collide with atoms in the air and breed new nuclear particles. These new particles start moving at great speeds in the same direction as the primaries, and are called secondary cosmic rays. Those secondaries which cannot pierce through 10 cm of lead, are called soft components of secondary cosmic rays. Bhabha's chief scientific contribution has been the

'Cascade' Theory of cosmic-ray showers, relating to the soft component of secondary cosmic rays. He worked out the detailed mathematical aspects of his theory. His cascade theory found a practical use when he refuted Heisenberg's idea about the nature of explosions found in high-energy cosmic-ray phenomena. He predicted that some particles in cosmic-ray showers, behaved neither like protons nor like electrons, so must be new kind of nuclear particles. At his instance, these particles were named *meson*. Bhabha developed what is called the *vector theory of meson*, in a Royal Society paper, as early as 1938. In Quantum mechanics, Bhabha devised a set of equations, for particles with any arbitrary spin. These are equivalent to D.F.P. (Dirac-Fierz-Pauli) equations in the three particular cases corresponding to spins 0, $\frac{1}{2}$, 1. In 1941, Bhabha was elected Fellow of the Royal Society.

In 1941, he was appointed reader in Theoretical Physics at the Indian Institute of Science, Bangalore. Between 1942-45, he was Professor there. At this time, he was associated with Cosmic Ray Research Unit. In 1945, he became Director of the Tata Institute of Fundamental Research, which was established with his efforts. During 1947-66, Bhabha was Chairman, Atomic Energy Commission, India. From 1954 to 1966, he was Secretary, Department of Atomic Energy, Government of India. It was due to his efforts that an Atomic Centre was established at Trombay. In his honour, it has been renamed as the Bhabha Atomic Centre.

Dr. Bhabha was awarded Adams Prize (1942), Hopkins Prize (1948), Padma Bhushan (1954) and Hon. Fellowship (1957) of the Royal Society, Edinburgh.

In 1951, Dr. Homi Bhabha was elected the President of Indian Science Congress. In his Presidential Address to the International Conference on the Peaceful Uses of Atomic Energy (held at Geneva, in 1955), he remarked, "For the full industrialisation of the under-developed areas, for the continuation of our civilisation and its further development, atomic energy is not merely an aid; it is an absolute necessity".

Bhabha was the pioneer of atomic work in India and placed the same on a sound footing. Bhabha talked of self-reliance. But, for the sake of expediency, he went ahead with collaborations, with the Canadians for the CIRUS and Rajasthan reactors and with the U.S. for Tarapur. He earned a reputation for being a hard negotiator.

Dr. Homi Bhabha, the founder of the Tata Institute of Fundamental Research, said, "....By fundamental research I mean basic investigations into the behaviour and structure of the physical world without any consideration regarding their utility whether the knowledge so acquired would ever be of any practical value." He further said, "The history of science has shown that genuine knowledge of the universe is always potentially useful for man not just because someday action may be taken on it, but also because 'every new knowledge necessarily affects the way in which we hold all the rest of our stock'.

None can forget, the tragic sudden news of the air crash of 24th January 1966. Among the victims who died were Dr. Homi Bhabha and three other V.I.P's (including a Brigadier). Unfortunately, he could not survive to see the commissioning of even his first atomic power plant at Tarapur.

Professor Daulat Singh Kothari — an embodyment of Science and Culture

The life and work of any genius is a source of encouragement to all concerned with the development of the society. Many a times the fame and praise earned by a genius takes him away from the vary framework on which his work is based. But this has not happened in case of Prof. D. S. Kothari, who has been consistently engaged in research. For decades, he is associated with the prime scientific and technological advisory bodies of our country. Besides this, he is heading and advising many religious and social organisations and thus encouraging lot of youths for social upliftment of India. Prof. Kothari is an embodyment of science and culture and thus playing a key role in the national reconstruction and scientific-revolution.

Daulat Singh Kothari was born on July 6, 1906, in Udaipur District in Rajasthan. He had his education upto M.Sc. in Allahabad. He had been a student of Meghnad Saha, the eminent physicist. D. S. Kothari got his Ph.D. from Cambridge University. He, with his ascetic streak, had no difficulty in overcoming the temptations of Indian Civil Service.

D.S. Kothari specialised in astrophysics. He laid the foundation of the 'theory of pressure ionisation', according to which very high pressure *alone* (unaided by thermal factors) could ionise materials (a suffice to smash the atoms). He calculated that this atom-breaking pressure is of the order of some hundred million pounds per square inch. He deduced that degenerate matter existing under high pressure and low temperature condition (as in white dwarf stars) cannot form an object having volume greater than a critical limit (size of the Jupiter planet). This reminds us of Chandrasekhar's theorem that no white dwarf can be more massive than 14 times our own sun.

Meghnad Saha failed to persuade the administrative sultans of the Allahabad Senate, in granting three increments to Kothari (these he would have earned, had he continued his valuable astrophysical research in Cambridge). Kothari joined Delhi University, in 1934. Soon he won the confidence and support of his Vice-Chancellor, Sir Maurice Gwyer. He remained Professor of Physics at Delhi University, from 1934 to 1961. During this period, from 1948 to 1961, he was, simultaneously, Scientific Adviser to the Ministry of Defence, Government of India. Here, he initiated useful research projects on behaviour of metals under intense pressure of explosive loads and also on ballistics, electronics etc. He reorganised the working of the Defence Science Laboratories with a veiw to:

(1) providing reasonably correct choice between competing weapon systems;
(2) suggesting continual improvement in weapons;
(3) conducting research in the development and design of new as well as older existing weapons with a view to their indigenous manufacture.

It resulted in setting up a new laboratory at Jodhpur, in the desert of Rajasthan. This laboratory is essentially concerned with the testing of weapons and equipment in the environments of dry heat and sandstroms.

Kothari's resourcefull thinking, greatly mitigated the lack of material resources for the development of Defence Science Organisation. Though a mastermind in weapon-technology, yet his nature and inclinations are rooted in non-violence and other Indian ethos. Kothari's association with many religious and charitable organisations amply corroborates the above fact. At the instance of Jawaharlal Nehru, Kothari wrote the book "*Nuclear Explosions and their Effect*". He states that such a book may be of "some use in directing the people's mind to the dreadful nuclear test explosions". This scholarly work has been widely honoured in Germany, Japan, U.K., and U.S.A.

In March 1961, Kothari was appointed Chairman of the University Grants Commission. He tried specially to rejuvenate science education in the Indian universities. He did his best to further the cause of higher education in India, giving it a direction best suited to the prevailing conditions. His report on education, called the Kothari Commission Report, sets forth policies and procedures, following which a revolution can be brought about in the educational system in India. He left UGC Chairmanship in early 1973. On January 26, 1973, he was honoured with *Padma Vibhushan*. In 1974, he was the President of Indian National Science Academy, New Delhi. At present, he is actively associated with research and teaching at Delhi University, in the department of Physics, a department which owes its world-wide recognition largely due to his efforts. Institutions, in the long run, become what the men behind them choose to make them. Kothari enriched Delhi University with many scholars. He lured the pure mathematician, Dr. F.C. Auluck, to the study of Physics. The two together found an excellent use for Ramanujan's famous theory of partitions of numbers. It was the determination of the sizes of broken-down fragments of long chains of molecules in high polymers (new fuels and fabrics like nylons).

Professor Kothari has in him the rarest combination of earnest work and sincerest humility. Every meeting with him, turns out into a fresh source of encouragement.

Jayant Naralikar (1938—)

"India is a Country with a long history of refined human culture. It has been, and it continues to be, the home of world's great religion. Its multilanguage literature is rich in the thoughts of great thinkers. We, the Indians, are proud to inherit, this legacy from our past", said Prof. J.V. Narlikar, the world renowned young Astro-Physicist.

Jayant Narlikar was born on July 19, 1938, at Kolhapur. He is the son of Professor Vishnu Vasudeva Narlikar. He got his early education from 1943 to 1953 at University Children's School, Varanasi. In 1957, he did B.Sc. from Banaras Hindu University. He obtained first division and first position at all school and university examinations.

In 1957, Jayant Narlikar went abroad for higher education. He joined Fitzwilliam House, Cambridge and took the Mathematical Tripos Parts I, II and III at the University of Cambridge, U.K., in 1958, 1959 and 1960. He obtained first class in Part I, became a

Wrangler in Part II and had a distinction in Part III. After getting B.A. degree of Cambridge he joined as a research student under the supervision of Professor Fred Hoyle. Narlikar did his Ph.D. in 1963 and M.A. in 1964. In 1976, he got D.Sc., from Cambridge.

Narlikar got many awards and scholarships. He was J.N. Tata Scholar at Cambridge from 1957 to 1963, and W.A. Meek Scholar (1960-61) at Cambridge. In 1960, he got Tyson Medal for Astronomy awarded by Cambridge University. He got Smith's Prize in 1962 and Adam's Prize in 1967, awarded both by Cambridge University. He was awarded Golden Jubilee Gold Medal of Institute of Science, Bombay, in 1973. During 1963-1969, Narlikar was Berry Ramsay Fellow at King's College, Cambridge, U.K. In the same year he became a Fellow, Royal Astronomical Society and Cambridge Philosophical Society. He was elected Fellow, Indian Academy of sciences in 1974, and Indian National Science Academy in 1976. He was Jawaharlal Nehru Fellow from 1973 to 1975.

In the year 1962-63 Narlikar was the Director of Studies in Mathematics, Fitzwiliam House, Cambridge, U.K. From 1967 to 1972, Narlikar was a Staff Member, Institute of Theoretical Astronomy, University of Cambridge.

Owing to his brilliant research work, Narlikar became internationally known and was invited to deliver many distinguished public lectures. Among them are, Lokamanya Tilak Lectures (1966) on "The Universe and Laws of Physics" at the University of Poona, Friday Evening Discourse (1970) at the Royal Institution, London on "The Universe and the Arrow of Time", Presidential address at the Marathi Science Congress (1973). Jalna, on "The Atom and the Universe". Golden Jubilee Lectures (1973) at the Institute of Science, Bombay on "Are New Laws of Physics Necessary?"

In September 1972, Jayant Narilkar returned to India to serve his motherland. He is presently employed as Professor of Astrophysics at Tata Institute of Fundamental Research, Bombay.

On November 13, 1976, Narlikar delivered the 10th Nehru Memorial Lecture on the "Role of Scientific outlook in the development of science and society." He explained that scientific investigation consists of experiment (E), observation (O) and deduction (D) (which he calls the 'EOD'). "Although the scientific outlook lies at the bottom of the 'EOD' and has arisen out of the development of science, it has proved useful to the conduct of human affairs in the wider context", he said. He urged an investigation by competent experts into the so-called "miracles" by the so-called demi-gods and miracle workers. If the "miracles" are proved to be frauds, the society will rid itself of some evils. If they are proved to be genuine it will open new field in the advancement of science.

There is a tendency in the human mind to ascribe strange natural phenomena to supernatural causes. Sometimes, superstitions are born out of ignorance of how Nature functions. This hinders the growth of science which is dedicated to the unravelling of the mysteries of Nature. Prof. Narlikar does not agree with the early human societies which ascribed divine powers to planets. He thinks that such assumptions arose from gnorance of what planets are and how they move. To substantiate his viewpoint, he quotes a recent circular (of which 186 leading scientists of U.S.A. were signatories), published in *The Humanist* (Sept-Oct : 1975).

"It is simply a mistake to imagine that the forces exerted by stars and planets at the moment of birth can in any way shape our future. Neither is it true that the position of distant heavenly bodies make certain days or periods more favourable to particular kinds of action or that the sign under which one was born determines one's compatibility or incompatibility with other people. In these uncertain times many long for the comfort of having guidance in making decisions. They would like to believe in a destiny predetermined by astral forces beyond their control. However, we must all face the world, and we must realize that our future lies in ourselves, and not in the stars..."

Prof. Narlikar is an advocate of the need for basic research in India. He thinks that the hypothesis that basic research is an expensive luxury which a developing nation cannot afford, is a short-sighted point of view. He said, "To ignore basic research at this stage would mean that we will have to keep on importing new ideas from abroad. This would be contrary to our policy of self-reliance. India has plenty of talent for basic research and it must be tapped and unearthed."

According to the Newton's Law of Gravitation, the force of attraction between two masses m_1 and m_2 separated by a distance d is given by $G\, m_1\, m_2/d^2$. Prof. Narlikar claims that the gravitational constant (usually denoted by G) slowly decreases by a few parts in a thousand million per century. Due to this, the moon will gradually move away from the earth and go around it more slowly. Recent use of accurate atomic clocks, shows that this may be happening although very slowly. He said, "It is too early to be definite about the conclusion since it has profound implication for the well-established theories of Newton and Einstein."

Dr. Narlikar said, "Astronomers are now trying to study the universe not just by seeing light or radio waves, but studying X-rays, infra-red radiations etc. This has now become possible with the help of high altitude balloons and space satellites because these types of radiations do not reach the surface of the earth. Complex molecules, similar to the ones associated with life on earth have been found in space. This gives rise to the possibility of life existing elsewhere."

While making plea on behalf of science, Narlikar cautioned India against an indiscriminate use of the inventions of science. He said, "The developed countries are beginning to experience some of the ill-effects of excessive and indiscriminate use of science and technology. We should try to avoid such evils like pollution, drug addiction, the break up of the family as a unit, when we seek to solve the existing problems with the help of science. Let us not end up as intellectual barbarians or technological savages, as the developed countries have been sometimes called. It is here, I think that we can draw on our rich cultural heritage—on the wisdom of our forefathers over many centuries. I am optimistic that if we are not blinded by traditions and dazzled by science but keep our eyes open, our country will make a triumphant entry into the year 2001."

Prof. Narlikar has written many research papers, popular articles and science fiction stories on topics in theoretical physics, gravitation, cosmology and astrophysics. He is actively engaged in the research work at TIFR, Bombay.

Sir Prafulla Chandra Ray (1861-1944)

The 'Father of Indian Chemistry', Acharyya Prafulla Chandra Ray was born on August 2, 1861, in East Bengal. His father, Harish Chandra Ray, a landlord was a man of high intellectual calibre. P.C. Ray completed his initial education in Calcutta. He saw in Chemistry a potential source of producing materials and resources for human benefits. P.C. Ray's interest in Chemistry can be attributed to the influence of extremely stimulating lectures of Alexander Pedler, who was then Professor of Chemistry at the Presidency College. In 1882, he won the Gilchrist Prize which enabled him to go to Edinburgh for higher studies.

At the University of Edinburgh, P.C. Ray got the B.Sc. degree in 1885 and D.Sc. in 1887. The subject of his Doctoral dissertation was 'conjugated sulphates of the copper-magnesium Group: A Study of Isomorphous Mixtures and Molecular Combinations.' Ray became acquainted with the famous chemists such as Marshall and Crum Brous at Edinburgh. While in Edinburgh, he wrote an essay entitled "*India: Before and after the Mutiny.*" In this, he criticised the British rule in India.

On his return to India, Ray had to struggle hard for a suitable job for a year. During this period he received support and encouragement from Acharyya J.C. Bose. He followed the foot steps of Bose in joining the Presidency College. Here he was appointed Assistant Professor of Chemistry, in 1889. He became an extremely inspiring teacher. He was lucid and lively in his exposition.

The authorities of the Presidency College maintained that the institution was mainly for teaching and they believed that research would involve wastage of time and money. So the research facilities scarcely existed in the College. Sir Alexander Pedler, the then Principal of the College, gave ample encouragement to Ray and helped him to acquire useful equipments and chemicals. C.B. Bhaduri, Pedler's lecture assistant, also helped Ray considerably in performing scientific experiments. P.C. Ray retired as Professor of Chemistry from the Presidency College after 27 years of active service. Later, he became the Palit Professor of Chemistry at the newly founded University College of Science. It is largely owing to his efforts that this institution received, the initial stimuli to become one of the pioneer centres of active chemical research in India.

P.C. Ray was a remarkable research worker. He used the forum of the Asiatic Society, Calcutta, to communicate to the general public, the results of his scientific investigations. During the last two decades of nineteenth century, Indian leadership in Science was in the hands of Dr J.C. Bose and Dr P.C. Ray. Both of them were actively connected with the Science Association of Mahendralal.

In 1894, Ray conducted systematic chemical analysis of a number of rare Indian minerals with the object of discovery in them some of the missing elements of Mendeleeff's Periodic Table. Though the results were inconclusive, yet in the course of his analytical investigations, Ray noticed the formation of mercurous nitrate. This finding of the new compound (a yellow crystalline deposit) was reported to the *Journal of the Royal Asiatic Society* (1896).

Following this publication, an unbroken series of papers on the nitrites were published in the Journal of Chemical Society, London. Ray and his pupil, N.R. Dhar published a paper on the vapour density of Ammonium nitrite when this paper was presented before the London Chemical Society, Ramsay and Veley warmly congratulated the authors. Professor Armstrong commented to Ray: "The way you have made yourself a master of 'nitrites' is very interesting."

In the University College of Science, Ray studied the compounds of metallic elements with organic sulphur derivatives, and examined the formation and behaviours of some of their simple derivatives. Under his able guidance a number of students conducted researches on double sulphates, chemical and physical properties of compounds of zinc, cadmium, mercury and so on. Under his leadership, a group of youngmen established 'The Bengal Chemical and Pharmaceutical Works' on April 12, 1901. Many other industrial concerns like 'The Calcutta Pottery Works,' 'Bengal Enamel Works' were floated, largely with Ray's inspiration and technical guidance. Ray thus became the founder of what has come to be known as Indian Chemical School and leader of the Indian Chemical Industry.

By 1902, Ray had completed his monumental work on the "History of Hindu Chemistry" which covered the period from the dawn if civilization upto the sixteenth century. Congratutions were showered on Ray by Bertholet in his fifteen pages review in the Journal des Savants (January, 1903). Arrhenius and many others accepted the pioneering role of Indian Chemists in the ancient ages. Referring to Ray's lecture in London delivered on tenth January, 1916, '*Nature*' commented in its March 23 issue:

"The lecture consists of a brief resume of original chemical research as carried out in Bengal in the last twenty years, and as an appendix a list of 126 papers. Some of these are of considerable value and interest, and indicate enthusiastic work on the part of this newly created school, which is mainly due to the example and work of Professor Ray himself."

P.C. Ray believed in *Swadeshi* and was admired by Gandhiji, Rabindranath Tagore and Jawaharlal Nehru. From his own income, he created a trust which supported a high school and several other organizations. His life came to an end on June 16, 1944.

Shanti Swaroop Bhatnagar (1894-1955)

S.S. Bhatnagar was born in 1894 and got his early education at

Lahore. He had studied under Prof. A.C. Ghosh (who was P.C. Ray's student). Bhatnagar used to say that although he was not a direct pupil of Ray, he was his 'grand pupil.' After taking the M.Sc. degree of the Punjab University from the Forman Christian College, Lahore, he went to England in 1919 and worked under Prof. F.G. Donnan at the University College, London. His subject was Emulsions and he obtained the D.Sc. degree of the London University in 1921. He also worked at the Kaiser Wilhelm Institute, Berlin for some time. He returned to India as Professor of Chemistry at the Banaras Hindu University, where in a short time he created an active school of physical chemistry.

In 1924, Dr. Bhatnagar was invited to join the Punjab University as the University Professor of Physical Chemistry and Director, University Chemical Laboratories at Lahore. His sixteen years stay there was characterised by intense research activity. Important contributions in the field of colloids, surface chemistry and photochemistry were made by Bhatnagar and his pupils. In 1926, he switched on to magneto-chemistry a field in which Bhatnagar and his pupils are considered as pioneers. He did outstanding work in this field.

When World War II broke out, the Government of India required the services, of Dr. Bhatnagar as Director of Scientific and Industrial Research. He responded to the call and came up to the Government's expectations. In spite of heavy administrative and advisory duties, Dr. Bhatnagar was able to take a personal interest in research work and several processes of great importance were worked out by him and his staff. Among these are anti-gas cloth and varnish. air-foam solution, vegetable oil blends as lubricants and fuels, unburstable containers, glass substitutes, dehydrated caster oil, and plastics from Indian wastes.

The work of Dr. Bhatnagar won many laurels. In 1936, the Government conferred on him the O.B.E. and in 1941, he was created a Knight. In 1943, the Society of Chemical Industry, London, elected him as Honorary Fellow and later a Vice-President. The same year, he was elected a Fellow of the Royal Society. Amongst universities which conferred Honorary Doctorates on him are Oxford, Patna, Allahabad, Delhi, Banaras, Lucknow, Agra and Sagar. He was President (1945) of the Indian Science Congress and of National Institute of Sciences. during 1947-48 He was awarded *Padma Vibhushan* (Gusra Varg) on Independence Day, 1954.

Bhatnagar's Chief hobby was Urdu poetry and his poems have been acclaimed as the embodiment of a soaring vision and a clear expression which do not attempt to preach dry sermons.

A born administrative, he was always in close touch with every branch of activity under his care. Quick decisions and tacit faith in his lieutenants were his characteristics which contributed considerably to the successful discharge by him of any assignment. His ability to get things done quickly, his dynamic energy which won for him the name of 'live wire,' his easy accessibility to one and all—these were responsible for the brilliant achievements of his career.

Dr. Bhatnagar was the architect of the CSIR and the UGC. He was the Founder—Director of CSIR. He served UGC remarkably in the capacity of its Chairman. During the World War II period, he planned the establishment of an organized research agency under the aegis of the Central Government. When India become independent in 1947, Dr. Bhatnagar was instrumental—to in establishing a vast net work of national laboratories in the country which are now associated with his name. In a short period of 1950-54 he planned and established about a dozen national laboratories in the country. Some of them are the National Physical Laboratory, New Delhi; National Chemical Laboratory, Poona; Central Fuel Research Instiute, Dhanbad; the NML, Jamshedpur; the CFTRI, Mysore; CDRI Luknow; the CSIR, New Delhi etc. All these national laboratories were created under CSIR which also planned organised research on peaceful uses of atomic energy in India. As a result of his planning in this direction, the Atomic Energy Commission was established under yet another dynamic Indian scientist Dr. H.J. Bhabha. Dr. Bhatnagar also served as secretary to the Ministry, Natural Resources and Scienctific Research.

Dr. S.S. Bhatnagar died on 1st January, 1955 at New Delhi.

T.R. Seshadri (1900-1975)

Tiruvenkata Rajendra Seshadri was born on February 3, 1900 in the small town of Kulittalai in Madras, He was the son of Rajendra Tiruvenkata and Namagiri Iyengar. He received his honours degree from the Presidency College, Madras after which he served the Rama Krishna Mission as a teacher for one year.

Seshadri worked as a University research scholar under the guidance of Prof. B.B.Dey in orgainc chemistry. He won the Sir William Wedderburn and the Curzon research prizes of the Madras

Univeristy for his excellent work on the Chemistry of Indian Medicinal plants. In March 1927, he went to Manchester and worked with Prof. Robert Robinson, Nobel Laureate, and recieved a Ph.D. degree in 1930. Dr. Seshadri travelled widely in Europe. He worked with Prof. Pregl, another Nobel laureate, and Prof. Burger in the medicinal chemistry, Department of Edinburgh University. He worked as research chemist at Coimbatore Agricultural College and Research Institute from 1930 to 1933. He joined the Chemistry Department of Andhra University in 1933, became reader in 1938, he became Prof. and Head of Chemistry Department, Andhra Universiry. He was also entrusted with the task of building the newly created department of Chemistry, Chemical Technology and Pharmacy. He put his heart and soul in performing his duties. As a result, he brought these departments to a high degree of excellence. He continued teaching and guiding research at Andhra University till 1949.

In 1949, Prof. Seshadri was invited to head the department of Chemistry, University of Delhi, by the then Vice-Chancellor, Sir Maurice Gwyer. By strennous efforts, he built an atmosphere of hard work and quiet thinking. Besides looking after a large number of graduate and post-graduate students, he managed to guide a group of about fifty research scholars. There was no Delhi University Convocation where Prof. Seshadri's students were not present to receive their doctorates ever since he joined the Department. Prof. Seshadri's efforts towards excellent teaching and research made it the centre of Advanced Studies in Chemistry of Natural Products.

Prof. Seshadri was very much respected by his students and other scholars. He considered hard work and constant study as the most important tools to achieve success. Due to his love, affection and able guidance, students from all over India and abroad used to come to him to do research even without any fellowship. He was a firm believer of *Gita* and always worked without bothering about fruits. "Arre mad man why don't you work....", he asked one of his student. "Sir, there is no incentive...." Prof Seshadri advised, "Arre fool what incentive I have, what incentive nature has...it always gives you pleasure...you are after maya—money...we should work and leave the result to God."

Once Prof. Seshadri caught some of non-serious research fellows doing extra remunerative work and skipping their prime research job for which they were getting fellowship. He remarked, "You people do not respect the value of research...you are not honest to the Scientific Organisation which is paying you. You are worse than a prostitute. How will our country progress if scientists are dishonest."

Prof. Seshadri won numerous awards and honours from India and abroad. He was elected Fellow of the Royal Society (London), Indian Academy of Sciences and National Institute of Sciences of India. He was a member of Deutsche Academic des Naturforsches (Halle) Leapldina. He had been the President of Indian Science Congress, Indian National Science Academy (1972-74), Indian Pharmaceutical Association, Indian Pharmaceutical Congress, Indian Chemical Society, Oil Technologists Assoication (North India Branch) and Royal Institute of Chemistry (North India Section). He was Chairman of the 8th IUPAC Symposium (1972). Prof. Seshadri had been an Adviser to the Ministries of Education, Agriculture, Industry and Defence, to Council of Agricultural Research, Indian Council of Medical Research, University Grants Commission, Department of Defence Research and Department of Atomic Energy. Prof. Seshadri had won Bhatnagar Award and Maghnad Saha Award. He won Acharya P.C. Ray Medal of Indian Chemical Society. He also got Padma Bhusan (1963) from the Government of India. Prof. Seshadri was awarded Hon. D.Sc. from the universities of Andhra (1966), Banaras (1968), Osmania (1968), Delhi, and Sri Venketeshwara. He was leader of the Indian Delegation to First Indo-Soviet Symposium on the Chemistry of Natural Products, held at Tashkent in 1968.

Prof. Seshadri published about 1100 original research papers on chemistry, utilization of Indian Natural resources, agricultural commodities, forest products and other allied subjects, in Indian and foreign scientific journals. He published two books as well.

Prof. Seshadri had an unquenched thirst for knowledge and love for humanity. He gave much of his time and money to needy students, many of whom stayed at his house while working for their Ph. D. degree. Dr. Seshadri remained attached to Delhi University as an Emeritus Professor after his retirement in 1965 till his death in 1975.

Inspite of being a great scientist of repute, he was fervently devoted to God and the Rama Krishna Mission. He founded the Vedanta Samiti of Delhi University. He believed that science cannot solve all the problems of life. He emphasised the need of spiritual and moral education to students.

Prof. Seshadri was a great nationalist, for he had contributed a lot to the development of India. He was once asked as to why he was continuing the old routine research in the chemistry of natural products and why he could not hit at the more advanced natural product research...He replied, "this is not the fact that I was incapable of doing very good work...I could also have gone to the developed countries to do an excellent work to fetch some high prize. But I preferred to stay back home, to train a large number of chemistry graduates and chemists with basic knowledge and training in advanced chemical research, so that they could develop a new field of their own in their later life...I continued to do research in the Chemistry of Natural Produces becauses this is what India could afford economically and also with a purpose that this may turn out to be the source of various indigenous drugs...."

In late 1974, Prof. Seshadri fell ill. He had to be hospitalised for stomach ulcer. But he continued guiding his research students and correcting their Ph.D. theses. He said, "I forget all my pains when I am discussing with my students." Again in September, 1975, he was hospitalised in Willington Hospital, Delhi. Inspite of the best efforts of the doctors and preparedness of hundreds of his students to donate any part of their body, he died on September 7, 1975. He was right in saying "Science cannot do every thing for man."

Raja Ramanna (1925—)

Raja Ramanna was born on January 28, 1925 at Mysore, Karnataka. His father B. Ramanna and mother Rukmini arranged his early education at Bangalore. He got B.Sc. Honours from Madras Christian College in 1945 and Ph.D. (Nuclear Physics) from London University in 1948. He has been awarded D.Sc. (honoris causa) from Mysore, Meerut, Dharwar, Sri Venkateswara and Sardar Patel Universities.

He is married to Malathi and has a son and two daughters.

In 1949, Dr. Ramanna joined Tata Institute of Fundamental Research, Bombay. He still holds a position of Senior Professor there.

In 1953, he was appointed as Head of the Nuclear Physics Division in Bhabha Atomic Research Centre, Trombay and became the Director of the Physics Group in December 1962. After ten years, he rose to the position of Director, Bhabha Atomic Research Centre and Member for Research and Development, Atomic Energy Commission. He has to his credit design, installation and commissioning of research reactors—*Apsara*, *Cirus* and *Purnima* By 1976, he became Chairman of the Planning and Co-ordination Committee of Reactor Research Centre at Kalpakkam, for planning and implementing a fast reactor programme for India.

His main work has been in the fields of fission physics and neutron thermalization. He has made a detailed experimental study of the fission process and has developed a stochastic theory to explain this process. This work has been very well received. He has made extensive experimental study of neutron thermalization in crystalline moderators, and in water. *He was amongst the first few to study the pulsed neutron problem in beryllium oxide assemblies—a work which was reported at the first Geneva Conference on peaceful uses of Atomic Energy.*

Dr. Ramanna has been the main architect of India's first nuclear explosion at Pokaran in May, 1974. He has participated in several international conferences on 'Peaceful Uses of atomic energy' at United Nations level and has to his credit about 50 scientific research papers published in national and international journals.

He was the Chairman of various committees and boards of national and international importance like India—Philippines Agency Project Committee for the utilisation of the research reactor at Manila for the study of solid state physics, Nora Committee for a joint project between the Norwegian Government and the International Atomic Energy Agency for the planning and programming of the zero energy reactor in Norway, and Bharat Electronics Limited, Bangalore. In 1963, he was made President of the Physics Section of the Golden Jubilee Session of the Indian Science Congress held in 1963. He is also the Chairman of the Board of Governors of Indians Institute of Technology, Director of the Board of Directors of Electronics Corporation of India Ltd. Hyderabad. He is a Member of the National Committee on Science and Technology, Indo-Soviet Joint Commission as well as Executive Councils of Jawaharlal Nehru University and Indian Institute of Management.

He is also a Fellow of the Indian Academy of Sciences, National Academy of Sciences and Indian Society of Engineers. He was President of Indian National Science Academy during 1977 and 1978.

Dr. Ramanna was awarded the Shanti Swarup Bhatnagar Memorial

Award for Physical Sciences in 1963, *Padma Shri* in 1968, *Padma Bhushan* in 1973, National Design Award of the Institute of Engineers (India) in 1974 and *Padma Vibhushan* in 1975.

Presently, Dr. Ramanna is Scientific Adviser to *Raksha Mantri* (Minister of Defence), Director-General, Research and Development and Secretary to Government of India for Defence Research in the Ministry of Defence, New Delhi.

M.S. Swaminathan (1925—)

Monkombu Sambasivan Swaminathan was born on August 7, 1925 in Kumbakonam in Tamil Nadu. His father Dr. M.K. Sambasivan, an eminent surgeon hailed from Monkombu in Kerala State.

In 1944, he passed his B.Sc., and in 1947, he did B.Sc. Agriculture from the Coimbatore Agricultural College, Madras University. After this, he started his research career at the Indian Agricultural Research Institute (IARI), New Delhi, with a study of the inter-relationship in the genus Solanum. He got the IARI Associateship in Genetics and Plant Breeding in 1949. During 1949-50, he has been UNESCO Fellow in Genetics at the Agriculture University at Wageningen, Netherlands. He got his Ph.D. from the School of Agriculture, University of Cambridge, U.K. in 1952. 1952-53, he was a Research Associate in Genetics at the University of Wisconsin, United States. The extensive research carried out by him at Wageningen, Cambridge and Wiscosin helped to elucidate the origin of the potato, Solanum tuberosum, the nature of polyploidy in this important taxon and its interrelationship with related cultivated and wild species. Using new techniques he was able to obtain previously unsuccessful hybrids and transfer valuable characters into cultivars.

On his return to India, he joined (in 1954) as Assistant Botanist at the Central Rice Research Institute, Cuttack. He was Assistant Cytogeneticist (1954-56), Cytogeneticist (1956-61) and Director (1966-72) at Indian Agricultural Research Institute, New Delhi. Thereafter, he was Director General, Indian Council of Agricultural Research and Secretary to the Government of India, Department of Agricultural Research & Education (1972—March, 1979). From April 1979 to April 1980, he was the Secretary to the Government of India, Ministry of Agriculture (Department of Agriculture & Cooperation), New Delhi. Presently, he is Member (Agriculture), Planning Commission Govt. of India, and its Deputy Chairman since 3.4.1980. Besides, these professional positions, Dr. Swaminathan has guided over 50 students in their Ph.D. thesis work and contributed about 200 research papers in national and international journals.

Dr. Swaminathan created a school of cytogenetics and radiation research. Under his leadership, a wide range of basic problems were thrashed such as the differentiation of hexaploid Triticum species, the origin of the dwarf cocunut palm, elucidation of the factors influencing the induction and recovery of mutations in high plants. Using wheat, barley and rice as test organisms, his extensive studies gathered considerable fundamental information about the process of mutation and factors controlling the phenomenon. It also helped to highlight (a) the potential mutagenic properties of some vegetable oils and (b) the indirect effects of irradiating the culture medium on which the test organism, Drosophila melanogaster was raised.

As Head of the Botany Division, and later Director IARI, he became convinced that the key to shattering the yield barriers in wheat lay in the dwarf, non-photosensitive plant types of the kind developed by the Nobel-Laureate Dr. N. E. Borlaug in Mexico. On Dr Swaminathan's initiative, Govt. of India invited Dr. Borlaug to visit India and review the wheat situation. This led to the obtaining of a wide range of dwarf wheat improvement programme designed to develop high yielding varieties of wheat suitable for Indian conditions and of a quality acceptable to the Indian consumers. Dr. Swaminathan and his school have made important contributions in other crops also including the development of short duration and widely adapted high yielding strains of rice (Pusa-2-21), and scented (Basmati) type 'Improved Sabarmati,' accomplishment of difficult crosses in potato and jute species. He is also responsible for (i) development of the concept of "crop cafeterias," "mid-season corrections in crop scheduling" and alternative cropping strategies for different weather conditions, (ii) purposeful manipulation of genes in improving the yield, quality and stability of performance of several economic plants, (iii) development of whole village or watershed operational research projects based on principles of ecology and economics, and (iv) development of disaster management strategies based on relief and rehabilitation measures in the most-seriously affected (MSA) areas and improved crop productivity in the most favourable (MFA) areas.

Dr. Swaminathan's contribution to the Green Revolution, can be indicated in the words of Nobel-Laureate Dr. Barlaug "The green revolution has been a team effort and much of the credit for its spectacular development must go to Indian officials, organisations, scientists and farmers. However, to you, Dr. Swaminathan, a great deal of the credit must go for first recognising the potential value of the Mexican dwarfs. Had this not occured, it is quite possible that there would not have been a green revolution in Asia."

He assisted in the initiation of the High-yielding Varieties Programme, Dry Land Farming Pilot Projects, Multiple Cropping Pilot Projects and the Intensive Cotton Development Programme. He developed the concept of "National Demonstrations" in 1964 in order to enable scientists to directly test and demonstrate the validity of their experimental findings in farmer's fields. He demonstrated the concept of "Seed Village" in the village Jounti in Delhi State. He initiated a national "Lab to Land" programme to commemorate the Golden Jubilee of the Indian Council of Agricultural Research.

Dr. Swaminathan organised Agricultural Research Systems for development in developing countries: (a) As Director of ICAR (1972-79), he brought about several structural changes to achieve a better match between form and function by organising the Agricultural Research Service (A.R.S.) and Technical Staff Service of ICAR. Influenced by this, the International Federation of Agricultural Research Systems for Development (IFARD) declared as per extract,. "The Agricultural Research Service of the ICAR is a model which we would recommend for consideration and adaptation by all developing countries as soon as possible." (b) Serving as President of the IFARD since 1978.

He has been participating in Expert Consultations and technical meetings organised by F.A.O. for over 20 years. He led the Indian delegation to the F.A.O. Council Session held in June, 1979. He also Chaired Commission II of the 19th Session of F.A.O. Conference held in November, 1979.

Among the several honours and awards, he has received, a special mention may be made of the Ramon Mogaysay Award for Community Leadership in 1971 recognising his multifaceted contribution as "scientist, educator of both students and farmers and administrator towards generating a new confidence in India's agricultural capabilities." He was awarded Shanti Swarup Bhatnagar Award for contributions to Biological Sciences in 1961; Mendel Memorial Award of the Czechoslovak Academy of Sciences for contributions to Plant Genetics in 1965; Birbal Sahni Medal of Indian Botanical

Society for contributions to Applied Botany in 1966; Silver Jubilee Commemoration Medal of the Indian National Science Academy for contributions to genetical and agricultural research in 1973; Barclay Medal of the Asiatic Society for contributions to genetics in 1974; K.L. Moudgill Prize for contributions to standardization in 1978; and Borlang Award in 1979. He was also awarded *Padma Shri* in 1967 and Padma Bhushan in 1972, by the President of India.

Dr. Swaminathan has been awarded honorary D.Sc. from Sardar Patel University (1970), Haryana Agricultural Univ. (1973), Andhra Pradesh Agricultural Univ. (1973), Andhara Univ. Waltair (1972), G.B. Pant Univ. (1974), Jodhpur Univ. (1975), Marathwada Krishi Vidyapeeth (1975), Kumaon Univ. (1975), Burdwan Univ. (1976), Agra Univ. (1978), Kerala Agricultural Univ. (1978), Sri Venkateswara Univ. (1979), and Univ. of Agricultural Sciences, Bangalore (1980).

The positions held by him in scientific/professional committees/academies at the *National* level are:

(a) Secretary; Indian National Science Academy (1969-72).
(b) President, Indian Society of Nuclear Techniques in Agriculture & Biology (ISNA)—(1971-77).
(c) President, Indian Society of Agricultural Statistics (1972-80).
(d) President, The Nutrition Society of India (1973-77).
(e) President, Indian Society of Genetics and Plant Breeding (1965 & 1975).
(f) President, Indian Society of Agricultural Economics (1977).
(g) President, Indian Society for Cotton Improvement (1975-76 and 1976-77).
(h) Chairman, Planning Commission Panel on Dry Farming (1967-68).
(i) Chairman, Planning Commission Panel on Irrigated Farming (1967-68).
(j) Member, CSIR Inquiry Committee.
(k) Member, National Commission on Agriculture (1970—75).
(l) Chairman, High Level Committee to review the functioning of the Central Water and Power Research Station and Central Soils and Materials Research Station (1975—77).
(m) Chairman, Committee of Scientists for examining the data relating to the wholesomeness of irradiated potato, onion, wheat.
(n) Chairman, Committee on Cooperative Training and Management.

(o) Chairman, Committee on International Collaboration.

The positions held by him in scientific/professional committees/academies at the *International* level are :—

(a) Vice-Chairman, Technical Advisory Committee to the Consultative Group on International Agricultural Research (CGIAR) sponsored by the Food and Agriculture Organisation of the United Nations, International Bank for Reconstruction and Development and the U.N. Development Programme (1971—76).

(b) Vice-Chairman, Protein-Calorie Advisory Group to the United Nations System (1972—1976).

(c) Chairman, Board of Trustees, International Council for Research on Agro-Forestry (1979 onwards).

(d) Member, Board of Trustees, International Maize and Wheat Research Centre, Mexico (1972—80).

(e) Member, Board of Trustees, International Crop Research Institute for the Semi-Arid Tropics (1972—80).

(f) Vice-President, Society for the Advancement of Breeding Research in Asia and Oceania (1977—1981).

(g) Chairman, International Scientific Committee, constituted to review the research contributions of the International Rice Research Institute, The Philippines (1975).

(h) Vice-President, International Congress of Genetics, The Hague (1963) and Moscow (1978).

(i) Chairman, Committee on the whole U.N. Conference on Desertification, Nairobi, 1977.

(j) Chairman, International Wheat Genetics Committee (1978—83).

(k) Member, Co-ordinating Advisory Committee, Rubber Research and Development Board, Malaysia (1978 onwards).

(l) Member of the Committee on the Application of Science to Agriculture, Forestry and Agriculture (CASAFA) of International Council of Scientific Unions.

(m) President, International Bee Research Association.

Dr. Swaminathan has been recognised as Fellow of the Indian National Science Academy (F.N.A.)—(1962); Fellow of the Indian Academy of Sciences (F.A.Sc.)—(1957); Honorary Fellow of the National Academy of Sciences, India—(1976); Honorary Fellow of the Swedish Seed Association, Sweden—(1971); *Fellow of the Royal Society of London (F.R.S.)*—(1973); *Foreign Associate, National Academy of*

Sciences of the United States—(*1977*); General President, Indian Science Congress, Waltair—(1976); *Foreign Member, All-Union Academy of Agricultural Sciences, U.S.S.R.*—(*1978*).

Professor Birbal Sahni (1891—1949)

Birbal Sahni, aptly described as 'Father of Indian Palaeobotany*' was born on November 14, 1891, at Bhers, a small township in district Shahpur, West Punjab. Eversince his childhood, he was attracted towards Nature and enjoyed collecting plants, rocks, and shells, etc. This inborn love made him interested to the study of Palaeobotany and Geology in the future years of his life which is evident from the vast collection of fossils of various kinds not only from different parts of India but the whole world so admirably organized in the museum of the Birbal Sahni Institute of Palaeobotany, adjacent to the University of Lucknow.

After graduating from the Punjab University, in 1911 he proceeded to England to enter the Emmanuel College, Cambridge. Here he obtained tripos in Natural Sciences and subsequently took up research work under the supervision of Professor A.C. Seward, the most celebrated palaeobotanist of his time.

Sahni's stay at Cambridge was remarkably fruitful in more than one way. He became a founder scholar, winner, and exhibitioner of the Sudbury Hardyman Prize. He took the B.Sc. degree of London University and attended summer semester at Munich under Professor Goebel, the renowned German Plant Morphologist. Simultaneously, he also spared time and took real pains to revise and adapt for the Indian students, Lowson's Text-book of Botany. In 1919, he received the D.Sc. of London University and came back home, full of knowledge, youthful vigour, and nationalistic bent of mind which became amply manifested in the years that followed and his multifarious activities.

After returning to India, he served as Professor of Botany for small tenures of one year each, at the Universities of Banaras and Punjab. It was in 1921 that he took over the Chair of Botany at the University of Lucknow and in 1933 he became the Dean, Faculty of Science. Despite of his heavy teaching schedule, he produced a steady output of original research work and made the Department of Botany as one of the best centres of botanical centres of research in the whole country, to which students were drawn not only from India but abroad as well.

---

*Study of the preserved vestiges of plant life of the geological past.

In recognition of the outstanding merit of his research work, the Sc.D, degree of the Cambridge University was conferred on him in 1929. In 1936 he was elected a Fellow of the Royal Society (FRS) London. He succeeded in pursuading the University of Luknow to start a new Department of Geology. He was asked to shoulder the responsibility of its Headship as well.

Sahni's research contributions covered such a vast range that no aspect of Palaeobotany in India was left untouched. Amongst a large number of fossil plants, described by him from Rajmahal Hills of Bihar was his most remarkable discovery of a new group of fossil gymnosperms to which he gave the name Pentoxylae. As Sahni said in his introductory remarks, this defies classification and presents a new problem in our understanding of the gymnosperms. Other major activities of his research are the discovery of a rich flora comprising palms, aquatic ferns, charophytes, and dicotyledonous fossils from the Deccan Intertrappean Beds of Madhya Pradesh. Finding these fossils so much like the modern plants, he propounded that they could not be older than early Tertiary Period. Similarly, from the nature and composition of microfossils recovered from the Saline series of the Punjab Salt Range, he concluded that the age of this series could not be Cambrian or Pre-Cambrian as considered by some geologists and as such he favoured the alternative Tertiary view. He also made significant observations on the related geological and palaeogeographical problems like Wagener's Theory of Continental Drift, Himalayan Uplift, Permo-Carboniferous life provinces, and eastward opening of the Himalayan geosyncline.

In addition to palaeobotany, Professor Sahni was greatly interested in archaeology too and published several valuable papers in this field as well. His memoir on the "Technique of casting coins in Ancient India" set a new standard in archaeological research. This won him in 1945, the coveted Nelson Wright Medal of the Numismatic Society of India.

Professor Sahni presided over the Botany Section of the Indian Science Congress in 1921 and again in 1938, during its Silver Jubilee Session. He also acted as a President of the Geology Section in 1926. In 1940 he received the unique honour of being elected as the General President of the Indian Science Congress. Besides these, he served a number of other organizations in various capacities. For instance, once he acted as General Secretary of the National Academy of Sciences and twice its President. He was one of the founders and subsequently President of the Indian Botanical Society. He was also the editor of its journal for a long time. He was elected Vice-President of the Indian Academy and the National Institute of Sciences of India. He simultaneously served as an Honorary Professor of Botany at the Banaras Hindu University and also received the honorary degree of D.Sc. from the Patna and Allahabad Universities. Among the prominent prizes and medals won by him are : Barclay Medal of the Royal Asiatic Society of Bengal for outstanding research in Biological Sciences and Sir C.R. Reddy National Prize (1947) in Natural Sciences.

Abroad he was a Fellow of the Geological Society of London and a Foreign Honorary member of the American Academy of Arts and Sciences. First in 1930 and again in 1935, he was elected a Vice-President of the International Botanical Congress and finally the Honorary President for the 1950 Session. Alas! he did not live long to receive this honour.

Besides being an outstanding scientist, he was a perfect gentleman and a great patriot. His refined manners and noble-bearing endeared him to everybody who came in contact with him. He was artistic by temprament and both a graceful writer and forceful speaker.

A Committee of Indian Palaeobotanists, to co-ordinate their activities and to issue periodical reports was formed in September 1939. Its first report entitled: "Palaeobotany in India" appeared in 1940. A Society named Palaeobotanical Society came into being on May 19, 1946 when eight members of this Committee signed a Memorandum for the formation of the Society. Thus a long cherished dream of Professor Sahni became a reality with the establishment of an Institute of Palaeobotany. On April 3, 1949 Pandit Jawaharlal Nehru laid the foundation stone of its new building at Lucknow. After a week, on April 10, 1949 Professor Sahni succumbed to a severe heart attack. It seems as if Professor Sahni was preordained to fulfil a mission and departed as soon as that had been achieved.

Few people in India have done so much for the cause of science and still fewer have put in the entire head and heart for the country as Professor Sahni did. He not only trained a dedicated band of young scientists but also placed India on the map of the scientific world. The country will ever cherish and salute his zeal and patriotic fervour.

Panchanan Maheshwari (1904–1966)

Panchanan Maheshwari was born on November 9, 1904 in Jaipur, Rajasthan. His father, Shri Bejay Lal, who was a clerk in a Hospital, spared no efforts in imparting his son, the best possible education. Bejay Lal worked in extra-office-hours to provide books for his son and thus inculcated in Panchanan a passion for them. It is no wonder, therefore, that all through his life, Panchanan used to seek solace in books, magazines, and scientific treatises.

He got his school education in his home town in Jaipur and in 1921, went to Allahabad for college education at the Ewing Christian College. He could not join the medical profession because of the weak eye-sight. While studying at the undergraduate level, he became tremendously interested in Botany and particularly in morphology, chiefly through the efforts of Dr. W. Dudgeon, an American Missionary teacher, who was the Founder-President of the Indian Botanical Society. Panchanan thus earned the degree of Bachelor of Science (1925), Master of Science (1927) in Botany, from the University of Allahabad. Dudgeon inspired and guided Maheshwari towards a D. Sc. degree which came in reality in 1931 from the same institution. Dudgeon shared with Maheshwari, his rich experience in morphology and microtechnique and highly impressed with Maheshwari's industry and devotion, came to take a parental interest in his progress. One day, Dudgeon told Panchanan, "A Hindu father believes his life is served if gave his son a good education and saw him settled in life. My son is dead, but I wish to leave behind at least one student who will carry on my mission. It will be a great satisfaction if I could make you progress ahead of me". After completing his education, Maheshwari expressed his gratitude to Dudgeon and begged him, "What could I do for you in return"? Dudgeon replied, "Do for your students what I have done for you". Maheshwari really fulfilled his expectations beyond measures, and the tremendous energy and enthusiasm put in by him in training a host of talented botanists stands testimony to this. In fact for over four decades, he remained the towering figure in Indian Botany.

Panchanan began his teaching assignment at Agra College, Agra, as a Lecturer in 1931. Due to his keenness to acquire and impart knowledge, he attracted many students and an active school of morphological and embryological investigations on Indian plants followed. He worked tirelessly in laboratory and at his home. His wife Shanti, whom he married at the age of 13, besides discharging the household duties, assisted him in the preparation of slides. He considered the expenditure on books and scientific materials more important than his household needs. As a result, his family underwent prolonged self-denial and hardships. He collected a large number of books, journals, and reprints, His students had a free access to these. His vast collection of botanical specimens, coloured slides of plants and portraits of botanists, reprints, books, and microscopic preparations, now (after his death) constitute the 'Panchanan Maheshwari Memorial Library' at the Department of Botany, University of Delhi.

Maheshwari was a man of conviction. On principle, he resigned his post at Agra in 1937 and remained jobless for few months. Subsequently, he served the universities of Allahabad from 1937 to 1939, Lucknow from July to September, 1939 and Dacca from 1939 to 1949. At Dacca, he joined as Reader and Head of the newly-started Department of Biology and was promoted to Professorship in 1947. In 1949, Maheshwari was invited to head the newly established Department of Botany at the University of Delhi which he served until his untimely death in 1966.

Although he was essentially a man of plant morphology and embryology and a specialist in angiosperms and gymnosperms, he encouraged and guided research work in many other disciplines as well such as cryptogamic botany, anatomy, taxonomy and experimental morphology. Scholars came to study under him from far and wide. For him only two type of students existed—the hardworking and the lazy. The latter found no place with him. He set high standards for himself and used to expect the same of his students. In his life time, he contributed about 200 articles and reviews and as many as 40 students received Ph. D. under his guidance. He never boasted of his accomplishments nor praised his students in their presence. This was because he used to believe in the dictum : One must learn to serve without expecting praise or thanks.

Maheshwari's early works include the development of gametophytes and embryo of *Boerhaavia diffusa* and the cause of sterility in *Albizzia lebbeck*. Genera such as *Asphodelus*, *Urginea*, *Hydrilla*, and *Ophiopogon* were also studied for their embryological characters. In early 1940, he reported a new type of tetrasporic 16-nucleate embryo sac in *Acalypha indica*. His critical reviews on the types of embryo sacs and male and female gametophytes are examples of real depths of knowledge and vast reading. After joining the University of Delhi in 1949, he with his colleagues (some of which were his former students) and new pupils began a systematic and thorough study of the parasitic families such as Loranthaceae and Santalaceae. About 100 families of angiosperms have been looked into for their embryological data by his school for clarifying the systematic position and relationships. His several publications on microtechnique speak of his interest in methodology.

His early writings highlighted the importance of embryology to physiology and genetics. His Presidential address to the Botany Section of the Indian Science Congress held in 1950 was entitled: "Contacts between embryology, physiology, and genetics". Here he stressed the need for initiating work on artificial culture of immature embryos and the production of the haploid embryos. The success in anther culture obtained in one-celled microspores and haploid embryoids, fruits, and seeds, and our understanding of the influence of accessory parts in the normal development of the fruits are worthy of mention. Test-tube fertilization in Papaveraceae and Solanaceae, over-coming of incompatibility in *Petunia axillaris*, induction of organogenesis in the endosperm tissue of several angiosperms have further proved his earlier predictions as sound and logical.

Economic Botany was also of his interest and his book "Dictionary of Economic Plants in India" is a valuable contribution to the literature on important economic plants of our country. Due to his insistance, the study of local floras was followed with great enthusiasm and the result has been the publication of the Flora of Delhi, a very useful book for those interested in the plants of Delhi.

While at Harward between 1945 to 1947, Maheshwari completed his magnum opus 'An Introduction to the Embryology of Angiosperms'. It appeared in print in 1950 and has been translated into Russian in 1959. This book together with 'Recent Advances in the Embryology of Angiosperms' (1963) which he edited is the most authoritative volume on the subject. He also edited with his colleague, Dr. Manohar Lal, a Text-book of Biology for the Secondary Schools. He was the driving force behind the formation of the International Society of Plant Morphologists and was until his death the Editor of Society's journal, Phytomorphology. He also served on the Advisory Boards of several other scientific journals, both in India and abroad. For training the budding botanists, he founded the Delhi University Botanical Society, and trained graduate and postgraduate students to organize seminars, debates, symposia, botanical excursions, run a student's magazine-*the Botanica*.

Maheshwari was the recipient of several honours. He was elected a Fellow of the Indian Academy of Sciences in 1934, Member of National Academy of Sciences of India in 1935, a Corresponding Member of the German Botanical Society and the American Botanical Society in 1947, Honorary Foreign Fellow of American Academy of Arts and Sciences in 1947, Foreign Member of the Kaiserliche Deutsche Akademie der Naturforscher Leopoldina in 1959, Deutsche Botanischer Gesselschaft in 1963, and the Royal Dutch Botanical Society in 1963. From 1959—1962, he served as the Biological Secretary of the National Institute of Sciences of India. The Mc Gill University conferred on him the degree of Doctor of Science (Honoris Causa) in 1959. He was also the President of the National Academy of Sciences in 1963. He was elected in 1965 a Fellow of the Royal Society (F.R.S.), London. He presided over the Botany Section of the Indian Science Congress at Poona (1949) and was the General President-elect for the 1968 session of the Indian Science Congress Association. He was the President of the Indian Botanical Society in 1961, and was awarded the Birbal Sahni Medal by the Society in 1959. The National Institute of Science of India awarded him the Sunder Lal Hora Memorial Medal in 1964.

Maheshwari lived his life for science. He was especially interested in History of Science and encouraged his students to study the same. In his Presidential address to the National Academy of Science in 1965, he pleaded the cause of scientists and scientific research. He was responsible for preparing a detailed report 'Botany in Indian Universities' for the University Grants Commission, New Delhi (1962). He championed the progress of Biology in India and gladly gave his time for revising university syllabi, organizing symposia and Summer Institutes, and participating in or presiding over committees concerned with the improvement of teaching and research. He did not fail to express his frank criticism anywhere and about anyone even about the bureacracy in science. On the one hand, he was receptive to viewpoints of others, on the other, he was independent in thinking quick and resolute in decisions.

Maheshwari travelled widely during his life span. In 1936-37, he was associated with Professor G. Tischler at Kiel and the eminent embryologist, Professor K. Schnarf of Vienna. He was a participant in International Botanical Congress, Stockholm (1950), Paris (1954), Montreal (1959), and Edinburgh (1964). In the capacity of a UNESCO delegate, he visited Indonesia in 1952 and Egypt in 1954. In 1956, he was a member of the Indian Team to study General Education in U.S.A., a Visiting Professor at the University of Illinois (1959). In 1964 he was on a lecture tour of USA. He was the guest of the Academy of Sciences of USSR (1958 and 1965), Germany (1961) and Australia and Poland (1965). In 1963, he presented an invited paper at the International Symposium on 'Pollen Physiology and Fertilization' held at Nijmegen, the Netherlands (1963). He was one of the Indian Representatives for the International Biological Programme held at Paris in April, 1966. In the later trip he also visited London and signed the Charter of the Royal Society, after being honoured with F.R.S.

Soon after his return from Paris and London (1966), sudden illness overtook him which proved fatal and he died on May 18, 1966. He is survived by his wife, three sons (two of them in botanical profession), and three daughters (one of them erstwhile a botanist), an echelon of colleagues, and a large number of students. Everybody concerned with Botany will remember him with respect and attention as one of the leaders of the twentieth century who gave plant morphology and embryology a high status in science.

Many botanists felt pride in paying tributes by naming new finds, living or fossil, cryptogam or phanerogam, after this patron of scholarship in Indian Botany. These are: *Ascarina maheshwarii* (Chloranthaceae), Swamy, *Isoetes panchananii* (a quillworti) Pant & Srivastava, *Maheshwariella bicornuta* (a compressed seed from the lower Gondwana of India) Pant & Nautiyal, *Oldenlandia maheshwarii* (a Rubiaceae) Santapau & Merchant, *Panchanania jaipurensis* (a hyphomycetes fungus) Subramanyam, *Entryblidiella panchananii* (an ascomycetes fungus) Mukerji & Dhavan and *Sepedonium maheshwarianum* (an imperfect fungus) Mukerji.

Atma Ram (1908—)

Dr. Atma Ram an authority of the manufacture of high grade optical glass, was until recently the Secretary to the Government of India in the Department of Scientific and Industrial Research, Cabinet Secretariate.

He was born on October 12, 1908. He got his university education from University of Allahabad, securing in 1931, the first-class-first position in M.Sc. (Physical Chemistry). The same university awarded him D.Sc. (Applied Photochemistry) in 1936.

He started his career in 1935, from the post of a Technical Assistant in Industrial Research Bureau, Government of India, and served there till 1940. Thereafter, in the same capacity, he served (1940—42) the Board of Scientific and Industrial Research, Govt. of India. He became a Research Officer (1942—44) in the Council of Scientific and Industrial Research, New Delhi. In the year 1944-45, he served as the Secretary, Central Glass Research Institute Committee whose Chairman was Dr. S.S. Bhatnagar F.R S. During 1945—49, he was an Assistant Director & Officer-in-charge of Central Glass & Ceramic Research Institute, CSIR, Calcutta. Having come to know of his potentialities, he was deputed, in 1946, by Government of India to go to Germany with the British Objectives Intelligence Service Teams to investigate the manufacturing processes of the German glass and ceramic industries. In 1948, he was deputed by the CSIR to the USA and Canada to visit glass and ceramic research institutes and factories and there he worked at the National Bureau of Standards as a guest worker in the Glass Division and the Optical Glass Plant for about three months. In the same year, he was elected a Member of the International Committee on Glass with its headquarters at Sheffield. Later, he was elected along with a dozen scientists from different parts of the world, an Honorary Fellow of the Society of Glass Technology, Sheffield—one of the World's most prestigious institutions devoted to research on glass technology. He is in fact the only glass technologist in Asia to have been elected to this coveted Fellowship. This was nothing but recognition of his outstanding researches on glass technology.

After his return from abroad, he became, in 1949, the Joint Director of CSIR and Incharge of the Central Glass & Ceramic Research Institute, CSIR, Calcutta. He rose to the position of the Director-General of CSIR, a body which now controls a net work of about 30 research laboratories in India.

The Central Glass and Ceramic Research Institute developed under the leadership of Dr. Atma Ram as a constituent laboratory of the CSIR whose director he became in 1952. This Institute is now reckoned among one of the world's distinguished centres of glass research. His declared policy of scientific research for achieving self-reliance got a practical shape through contributions which the Central Glass and Ceramic Research Institute made under his leadership. The production of foam glass, selenium-free red glass and insulating bricks from waste mica are some such processes developed by him whichave generated a chain of new manufacturing possibilities in India. His work on the origin of colour in copper-red glass is reckoned as a outstanding contribution to fundamental research on glass.

While in Government Service since 1935, several investigations carried out under his leadership could not be published and remained in the departmental reports, due to their being for war requirements. During this period, he was on several important committees in different capacities. He was Member, Glass Panel and Ceramic Panel of Planning and Development Department, Government of India; Member and Secretary Glass and Refractories Committee, CSIR; Chairman, Glassware Sectional Committee, ISI, New Delhi; Member, Chemical Standards Sub-committee, ISI; Member, Optical Glass Production Committee, Ministry of Industry and Supply, Government of India.

Lenin Soviet Technological Institute of Leningrad awarded Dr. Atma Ram the Honorary Degree of Doctor of Technology in Chemical Service for his contributions to chemical sciences. He is Hon. Doctor of Sciences of the Banaras Hindu University and the Andhra University.

Dr. Atma Ram has been the first receipient of S.S. Bhatnagar Medal (1959) of the Indian National Science Academy for outstanding contributions to technological sciences. He was elected President (1969-70) of the Indian National Science Academy, the premier science academy of the country. Prior to this, he was elected President of the Indian Science Congress 1967-68, the largest and the oldest scientific association in India.

Dr. Ram has behind him a distinguished scientific career of nearly 45 years devoted mostly to applied research. One of the distinguished applied scientists of India, he is ranked among the world's leading glass technologists of today. He is an authority on the manufacture of high grade optical glass in India. He has contributed about 35 papers to Scientific Journals. Since June 1977, he is on the Editorial Advisory Board of 'Manthan,' quarterly Journal of Deendayal Research Institute, New Delhi :

He is an ardent believer in scientific research for economic development and has throughout his long scientific career, tried to give practical effect to his philosophy. His most important achievement in pursuance of this philosophy has been the development of the process for the manufacture of optical glass, which is one of the prized strategic materials for defence and in industry. It is a closely guarded secret for strategic reasons, of a few advanced countries of the world.

Dr. Atma Ram is Member of Merit, International Commission on Glass. Recently, he resigned from the chairmanship of National Committee on Science and Technology, New Delhi, the country's topmost body dealing with its science policy.

6

Science and Dharma

Burtrand Russel said, "Science in its beginnings was due to men who were in love with the world. It began as the pursuit of truth."

'Science' can be regarded as that branch of knowledge which establishes reasonably relationship between man's senses and his observations about nature and which develops a thought-process for the study of supernatural. For doing so, care must be taken that our inferences are independent of the individuality of the considered objects and places.

Despite all the violence amplified beyond imagination by abuse of science and technology and despite all the inhuman applications of science, science guided by DHARMA is the only hope for mankind. What lies at the root of man's troubles and suffering is not lack of pursuit of knowledge but greed, worship of power and other symtoms of dishonesty, selfishness, vested interests etc.

Now let us examine what *Dharma* (which is not just religion but is far deeper a connotation) means :

Pandit Deendayal Upadhyaya, a socio-political reformer said, "Dharma is a very broad concept. It is concerned with all aspects of life. It sustains the whole world. Dharma is higher than both the Legislature and the Judiciary". He further said, "A secular state does not mean a state without religion. The word Religion merely means a tenet and those who believe it are called sects like the Jains, the Sikhs, the Christians."

Dharma represents ten values/commandments—perseverance, forgiveness, self-control, absence of theft, purity, control of senses, knowledge, learning, truth and absence of anger. According to *manusamriti* (a great Hindu epic), *Dharma* is :—

धृतिः क्षमा दमोऽस्तेयं शौचमिन्द्रिय निग्रहः ।
धीर्विधा सत्यमक्रोधो दशंक धर्मलक्षणम् ।।

Rishi Vedavyas, in Udyoga Parva of *Mahabbharata*, said :

धारणाध्दर्मइत्याहुर्धर्मो धारयते प्रजाः।

[*Dharma* is so called because it preserves all subjects (body and soul)]

In Bharatiya (Indian) thought, another explanation of *Dharma is*—

यतोऽभ्युदय निःश्रेयस् सिद्धिः स धर्मः।

(*Dharma* is the cause of material and spiritual prosperity)

One may note that even the physical prosperity (attached to science) does not come, merely from discovery or invention but from production (i.e. application of science) which again requires a direction from *Dharma*.

A *vedantist* in the search of supreme *brahma* and a *scientist* in the search of *absolute truth* are the same.

Until very recent times, theology admitted *free will* in human beings and thus showed affection for natural laws in the universe. In the times of Newton it was held that God had created the world in accordance with a Plan. The natural laws were the embodiment of this Plan. Gradually, the theologists began to give more emphasis to sentiments and so intellectual traditions of religion got blurred. This drift from head to heart blunted the edge of logic, and thus respectability of religion suffered. This unfortunate trend is more or less continuing till today.

Now a days, religious people respect science because of observations, reasons and logic inherent in the scientific methodology. Scientists today respect religion sometimes due to some intellectual traditions of religion, sometimes due to their own good citizenship for defending virtues and property, and sometimes due to their failure to understand some aspects of nature. The real need of the day is a proper admixture of theology, religion, science, humanity etc. The *Dharma* encompasses all such virtues and so the human welfare requires more and more of *Dharmic* people on our earth. The above concept of Dharma is a fundamental contribution of Hindu (Indian/Bhartiya) society to the world (rest of humanity).

Theorizing is fundamental to scientific activity. What is subjected to experimental observations, is not nature (as is many a times misunderstood) but conjectures about nature. The scientific revolution marks a shift not only from experience to experiment but also from seeking certain truths to theorizing about probable truths. In science reality must be regarded as theory.

Man has no future without science. But there has to be something more (*Dharma*) than science. If science and technology are to benefit man, science must become a part, an integral part of culture.

Men today are richer in their possessions but poorer in themselves. This is because many scientists reject religion and spiritualism as a set of superstitious beliefs. Consequently, many of the values advocated by religion are lost to the best part of mankind.

Both science and religion hold great promises in the minds of the people. Failure of either to fulfil these hopes can lead to disenchantment. The failure is due neither to science nor religion but to the attitudes of their practitioners in understanding and adopting *Dharma*.

Science tells us about 'what and why' of an object, process, but not about 'what should be'. Science invents truth but not the direction or mode of its use. Thus Science is a dead body of knowledge and *Dharma* gives it consciousness (soul).

Science pertains to knowledge and actions, and *Dharma* gives them proper direction. Proper co-ordination of knowledge and its correct use is the burning need of modern society. Science and *Dharma*, each is an attempt (search) towards oneness. In fact *Dharma* encompasses science.

Most of the scientists believe in the infinite capabilities of *Dharma*. An example is that of Albert Einstein, the greatest scientist of the modern time. He had hung on the bare walls of his study room, two portraits—one of Mahatma Gandhi and another of his German musician friend. "The greatest man of the age", that is how Einstein described Gandhi.

The following Sanskrit saying is worth mentioning—

"धर्मेणहीनः पशुभिः समानाः" ।

Swami Vivekanand said, "A man without religion (more exactly *Dharma*) is a man without heart."

The purpose of science is expression and not creation. Science today is trying to know the ultimate which is also the aim of *Dharma*. Science and *Dharma* appear to be conflicting to those who don't understand these concepts properly. In fact, *Dharmic* people should be happy for the scientists are helping them to achieve their long cherished objectives.

It is necessary to deal with the real suspicion and even hostility to science that has been generated in recent years for destruction, and the universal fear of the further use of science in more and more horrible forms of destruction. A faith in *Ahimsa* (non-violence) can ease the situation. But unfortunately it is *himsa* (violence) which is highlighted in human history and even in film industry. This is sometimes due to narrow objectives and sometimes due to the lack of humanity in the concerned individuals who operate in history-writing and film-making. Karl Popper, one of the greatest philosophers of science, in his book *The Open Society and its Enemies*, Vol. II, p. 270, writes :

"There is no history of mankind, there is only an indefinite number of histories of all kinds of aspects of human life. And one of these is the history of political power. This is elevated into the history of the world. But this, I hold, is an offence against every decent conception of mankind. It is hardly better than to treat the history of embezzlement or of robbery or of poisoning as the history of mankind. *For the history of power politics is* nothing but the history of international crime and mass murder (including it is true, some of the attempts to supress them). This history is taught in schools, and some of the greatest criminals are extolled as its heroes."

After having reviewed science and Dharma it can be concluded that for the proper development and utilization of science and for the welfare of humanity, the world has to abandon war and such other ills. The scientists, the technologists, the medical men, the historians, the economists, the politicians and other social workers, should cultivate and practise the virtues—humanity, *ahimsa*, *Dharma* etc., so that real public service should be the goal of their work. There is no reason why scientists and non-scientists should not be organised to this end.

7

The Impact of Science on Modern Life

After understanding pre-science and Science, one must proceed to know the impact of science on modern life. Starting from the importance of science, this will require examining the aspects and situations where life has been made happier or otherwise.

Importance of Science

Science means knowledge and it has two main objects— to enable men to *do* and to *know*. Every human being is directly and vitally concerned with science. Pure science has moulded his philosophy of life and applied science has determined almost the whole of his material surroundings, his chances of life or death, poverty or affluence, freedom or slavery. Science gives an intelligible picture of what one perceives by sense in so far as it can be expressed in terms of numbers, ratios, sizes, shapes, weights and motions and all the qualities and units derived from these.

Science prevents suffering, cures diseases, lengthens life, wings us through space, transports us on land or water, builds our houses, makes our clothing, preserves our food, purifies our water, increases our enjoyment, deepens our understanding, warms us in winter, cools us in summer, and helps us day and night in many different ways. It has profoundly altered our life.

Science, customarily used in a narrower sense to denote ordered knowledge based on observations and experiments, as a factor in human life is exceedingly recent, some 400 years old. Since man is reasonable by nature, science has evolved out of philosophy, culture, mythology and religion. During the first two hundred years of the growth of science, it remained a pursuit of the learned, which did not affect the thoughts or habits of ordinary men. It is only during the last two hundred years that science has become an important factor in determining the everyday life of common people. The influence of science upon man is continually increasing and is likely to increase further. Science must provide a new philosophy for action, enabling man, irrespective of origin, to rise to full stature. Science holds great promise in the minds of the people. Its performance, in the ultimate analysis will be judged by the impact it makes on the lives of the people. The external circumstances of our daily lives are almost wholly dependent upon science and there is scarcely anything in the modern home that has not been made by processes whose principles, involve the scientific advances of this modern time.

Those living in the modern age of science have realized that science has provided authenticity to some of the traditional beliefs and has dissolved many superstitions.

In considering the effect of science upon modern life, one has to examine the nature and scope of science, the increased power of manipulation derived from scientific technique and the changes in the social life. We must also see to what extent science can help us in solving the social problems like poverty and hunger among masses of people, widespread illiteracy and ignorance, large scale crime, drug addiction, alcoholism and things of this kind.

The Scope of Science

The model in modern science is Physics, which bases itself on principles derived from the study of 'inanimate' objects (or more accurately on principles derived from the study of those objects which are assumed to be inanimate). But Biology (the study concerning living organisms) is slightly an exception when it concerns itself with 'reproduction' under certrin conditions. No branch of science deals with consciousness, purpose, intention, will, wisdom, morality etc. Science deals with interactions of bodies with outside forces. It tells how the bodies *react* to forces but it cannot tell how they *respond*. Science cannot tell us what we *ought to do*. It can only tell us *how to do* or what will be the result of doing certain things.

Modern psychology, becoming more scientific, must be welcomed. But, in the process, elimination of considerations of interiority has to be discouraged otherwise reducing man to machine (reacting to external stimuli in a preductable manner) would be going far from *truth* and *reality*.

It is curious to note that the man in the street has begun to believe thoroughly in science, while the man in the laboratory has began to lose his faith in it. This is happening due to the limited scope of science in the development of humanity.

Applications of Science

Numerous applications of science have yielded to man many material things and helped him in despelling many superstitions. These have made him confortable and happier. With the increase in the applications of science, rational thinking has developed significantly.

Science is helping us in visualizing the possibility of a new bridge between which now exists and that which does not exist. It helps in our creative imagination——a means of dealing with the unreal and the unknown. J. Brownowski writes in *The Common sense of science*, "If any ideas have a claim to be creative, because they have created something, then certainly it is the ideas of science."

Science has profoundly modified the forms of economic organizations and functions of states. Gun powder was the first scientific discovery of importance. It led to a fortified defence system of states against agreessions. Since then there has been a large scale improvement in the quality of weapons.

The trend of science at any time is made by the needs (material needs) of the society : Navigation before 18th century, industrilisation thereafter and at present the liberation of personality. Discovery of Mariner Compass and then of different techniques in navigation explored new islands and new routes. It led western Europe to dominate in seapower.

Discovery of steam, electricity and oil and their applications have put the scientific knowledge into large scale use. At present some countries fulfil all their needs only on the basis of their oil abundance. Oil has even become an important factor in certain quarters of international politics.

Industrial revolution, as a consequence of the discovery and techniques of manufacture of different items of human need, took place in the last two centuries in different countries. This transformed their social set up and the economic structure.

The discoveries of aeroplanes, jets, rockets and other ultrasonics added new dimensions to science. These made the globe compact. Atomic energy is among the recent developments. The mass-energy equivalence has quantified this discovery, giving to man tremendous energy sources. It may be used for peaceful as well as for war purposes.

The scientific discoveries that concern man directly and individually are those of Biology. These have helped man a lot medicinally and surgically in the last two centuries. Real indepth studies have been made after the discoveries of Circulation of Blood and that of Microscope.

The intellectual and labourious zeal of many scientists has resulted in knowing the various aspects such as causes, effects and treatments of many deadly diseases like Typhoid, Tuberculosis, Cholera, Plague, Malaria, Diabetes, blindness etc. Discovery of technique of vaccination helped in discovering the vaccines for many of the deadly diseases. The use of penicillin, streptomycin and other sulpha drugs has helped in controlling the spread of diseases. Pathalogical and antiseptic techniques resulted in conducting numerous tests and thus the quality and quantity of germs present anywhere can be known.

The studies regarding Evolution, Heridity and consequently Genetics have made inroads in the unknown about man. The study of inheritance, the skills and other qualities of parents. likely to be transformed, to their offsprings has come within the range of man's competence. Artificial breading of some plant and animals has been attained. Inductions of desirable mutation synthesis of genes are now possible. The applications of mathematics, Chemistry and Technology are some of the most modern studies and are expected to give bewildering results.

Test Tube Baby : The attempts to produce a test-tube baby were going on for the last few years. But this was appearing to be an impossibility because it is almost impossible to create conditions (in the laboratory apparatus) similar to those which exist at the time of fertilization in humans. This was simply because such conditions and environments are not merely the outcome of biological entities but of pituitary glands (dependent upon the mental working) of the male and the female involved. Also, till recently, it was believed to be outside man's purview for otherwise there would hardly be left any difference between God and Man.

Recently, the most significant success of man in understanding the nature has come to light. Two ladies (Mrs. Lesley Brown and Mrs. Bela Aggarwal), the fallopian tubes of both of whom were blocked by nature, have been able to deliver girls. In each case, fertilization (the fusion of male 'sperm' of the husband with the 'egg of the wife) was made to take place in the laboratory rather than inside the female reproductive organs. This remarkable success (the birth of Louise Brown) was first attained in England on July 25, 78 by Dr. Patrick Steptoc and Dr. Robert Edwards. Secondly, again a girl (Durga Aggarwal) took birth on Oct. 3, 1978 at 11 A.M. in Calcutta (India) to a couple——Mrs. Bela Aggarwal (31) and Mr. Pravat Kumar Aggarwal (36) by the efforts of three doctors————Dr. Saroj Kanti Bhattacharya (Gynaecologist), Dr. Subash Mukherjee (Physiologist) and Dr. Sunit Mukherjee (Bio-Engineer). The baby weighing 3 Kg. 350 gms was delivered 7 days earlier than expected. Five ova were collected from Mrs. Bela in late 1977, out of which only three could be fertilized (in a test tube apparatus) by the sperms of Mr. Parvat Kumar Aggarwal. After three and a half days, the matter (fertilised ova) was cooled frozen slowly and eventually plunged in 'deep freeze' in liquid nitrogen at a temperature of minus 195 degrees centigrade for 53 days. All the three fertilized ova were then injected into the womb of the mother in Jan. 1978. However only one ovum survived and grew and delivered on Oct. 3, 1978.

About this success of test-tube baby, Dr. R. Lizerkka, professor of gynaecology, Keioh University, Tokyo said, "It is a great success. This method (of keeping the ova in deep freeze) can be developed to form an embryo bank". Dr. Akira Iritani, professor of zoology, Kyota University added, "so far the method had been applied with limited success, on cattle, in U.K. and Canada. The method of freezing the embryo, before transfer,is more valuable than the one adopted by British doctors".

Genetics, the science of anquiring various characters by an individual, can really help man in two ways : by improving this efforts to breed better plants and animals for use in agriculture, by helping him to understand himself. The various branches of science prducing such impacts on modern life can revolutionize the world.

Horrors of Science

There are many grave dangers facing man today. There is the population explosion; massive malnutrition; violence rampant in society, threat of nuclear and biological weapons; industrial pollution and so on. Most of these problems arise due to inadequate knowledge or due to misuse of science and technology. Science, on the one hand has increased human happiness, and on the other has introduced new evils and intensified some old ones. Science has made tyranny more acute and war more horrible.

Science has afforded man the most gigantic power to destroy his fellows. Though more depends on the people who make use or misuse of a scientific discovery, yet the invention capable of destruction creates the intention of its misuse. Real culprit is *power politics* about which Karl Popper (one of the greatest philosophers of Science) writes : "the history of political power is elevated into the history of the world. This, I hold, is an offence against every decent conception of mankind."

Science has multiplied the powers of the war-makers. The modern weapons can kill more people more secretly and more unpleasantly than those of the past. The atomic and hydrogen bombs became possible because of the discovery of the theory of relativity by Einstein.

In the early years of World War II, the USA government decided to develop an atomic bomb with the object of deterring Hitler to use the atomic bomb (in case Germany was able to develop an atomic-bomb). But the fact remains that the democratic USA government which succeeded in making the atomic bomb did also use it against Japan. This is till now, the most violent act in man's history. Droping of two atomic bombs on Japanese cities Hiroshima and Nagasaki reduced the two cities to dust and ashes, in an instant and without any warning. What Hitler would have done if Germany had the atomic bomb, is certainty beyond imagination. It follows that the effective decentralization of decision-making process could have discourage gross misuse and perversion of power.

Modern technology by accelerating the industrial progress of the world, has added to man's happiness. But it has deprived man of his enjoyment in handicraftmenship. Mass-manufacture technology has turned some skilled workers into automation experts and thrown the rest into the unemployment market. In many countries and more so in the case of India, automation and use of heavy machines are adding to the already severe problems of unemployment. In fact in a country like India, science and technology should be geared to the needs of the rural and poor majority people.

Enviroment pollution causing Health Hazards is considered as a manmade change that adversely effects, the quality of man's natural surroundings. The total costs of such changes equal or exceed the total benefits to society. By polluting the air he breathes, the water he drinks and the food he eats, man is reducing the chances of his own survival.

Environment Pollution is the outcome of Industrilization and is among the modern problems faced by developed countries and knocking at the doors of developing countries. So far so the United Nations Organisation, in 1972, created the United Nation Environment Programme (UNEP). The Indian Society of Naturalists Baroda (INSONA) is cooperating in this Programme of environment conservation for improving the general quality of life. June 5, 1978 was declared by United Nations as the World Environment Day. It provoked serious thoughts and many seminars were held for creating a general awareness among the people about environmental problems.

Among the several surveys for the analysis of Industrial pollution, is *the one conducted in 1971-72 by the Institute of Public Health and Industrial Hygiene, Calcutta. It revealed that on an average 100 tonnes of dust-carban-sulphur particles are deposited in a square mile of surface area during a winter month. In fact Air Pollution is the biggest health hazard. Since one cannot live without inhaling air, so all men and women of all ages are exposed to polluted air (due to the heavy pollution from various industrial and automobile exhaust). The children are most effected by it. A study in London (Lowther 1971) on the role of pollution in causing chronic lung diseases has led to the establishment of the fact————infection of lower respiratory tract leading to bronchitis and penumonia among children is correlated with the degree of air pollution of their town of birth.

According to a study* environmental sanitation in India (Kwata 1963) the causes of environmental pollution are mainly dusts, fumes, mists, vapours and gases. The same study identifies the sources of pollution as wastes or effluents from industries. are minerals like quartz and metal like lead, cadmium, zinc, manganese, magnesium etc., and machine tool lubricants, alkaline wastes from textile mills, lime water from tonneries, wastes containing lignite, dye-stuff, nylons, plastic, rayon, and vapour-producing mercury and gases like carbon monoxide, hydrogen cyanide and oxides of nitrogen etc. In Delhi, Yamuna river alone carries away every day 200 million litres of human wastes and 20 million litres of industrial effluents discharged into it by Delhi based industries. About 15,000 chemical compounds are widely used in industry, agriculture and commerce. Yet only a few have been thoroughly investigated as to know their adverse affects on human health.

---

*YOUR HEALTH June 1979, of I.M.A., page 166

Pollution whether in air, water or food, is causing ever increasing health hazards leading to many diseases such as byssonosis, pneumoconiosis, systemic poisoning, dermatoses, cancer (one of the biggest scourges of modern life) and ploymer-fume-fever etc.

Today, Textile industries in India, employ nearly 1·5 million workers of whom 53 per cent (8 million) are in cotton textiles. Out of these textile mill workers, 20 per cent are victims of byssinosis—a disabbling respiratory disorder caused by inhalation of cotton flax or hemp dust. The exact chemical cause of this disease is not known so far. Besides, the ubiquitous cotton dust, there are the dyes and chemicals widely used in textile mills. A revealing Indian study (1970-75) sponsored by ICMR, was conducted by research workers from KEM & MGM Hospitals and Central Labour Institute (all in Bombay), in three cotton mills in different stages of modernization. It revealed that the over all incidence of byssinosis in exposed group (workers having different length of service) was 12 per cent on the whole.

Among the less known factors affecting an industrial worker's health is thermal stress----the physiological effects of high temperature and humidity. These cause heat stroke, vomitting, giddiness, nausea, unconsciousness, increase in the rate of heartbeats, headache, and loss of appetite. Besides heat radiation, industrial pollution may be caused by X-rays, used in different industries to detect flaws in metal castings. Severe injuries to the eyes and skin can be caused by ultra violet radiation and the radiant heat of molten metals——a common occurence among workers in the foundries.

Noise Nuisance caused by the operation of various machines and instruments used in the applications of science, is also a factor to be reckoned as a health hazard. Harmful effects of this nuisance are annoyance, fatigue, mental tension, irritability and emotional disturbances. Hearing loss, temporary or even permanent may also be caused. The physiological effects can vary from constrictions of peripheral blood vessels to dilation of pupils, muscular tension, increased diastolic pressure and glandular stimulation.

Ideally, an environmental problem should not be allowed to arise in the first place. More realistically the best that can be hoped for is probably to avoid some the problems and threats that might otherwise materialise.

Now, it is not the workers alone engaged in industries but also the public in the industrialised localities who are victims of environmental health hazards. It is in the common interest of all to tackle the pollution problem. This needs an awareness about the various aspects of the problem. This will create consciousness and concern among the concerned government officials, industrialists and the public at large. Though improving merelly the lot of people by dedicated strong capacious patriots is always a permanent solution, yet some immediate measures are needed. Adequate legislation against hazardous pollution and its effective implementation is needed at the Governmental level, and designing methods and devices for decreasing the hazards of pollutants is needed at the level of the scientists.

Limitation of Science

It is a fundamental assumption of all scientific inquiry that what one is investigating has no interiority (i.e. it is dead). The object under inquiry is supposed to have no consciousness, purpose or intention of its own i.e. it reacts to forces, but it cannot *respond*. The study of the property of 'reproductability' under certain conditions, is only an exception.

One has to decide what is good or desirable and than consult science as to how to get it, but science cannot tell what is good. Science summarises the observations and provides reasoning to them. Science is just one kind of knowldege on which the decisions are based.

Science summaries what has happened, in the form of laws. Assuming conditions to be unchanged, these laws are applied to the past and future. This is not justifiable, for the planetory orbits and other elements of our solar system are undergoing small changes. In fact past and future conditions cannot be wholly known and so no past and future events can be certainly deduced from science (present science). Thus science can infer with certainity only about the present.

Moreover the spirit of analysis in the scientific outlook, has got its own limitations for part truths may not necessarily lead to whole truth.

Inspite of these limitations, science can go a long way to decrease human misery and sorrow, and increase human happiness.

Human Happiness--A scientific Indian Interpretation

Happiness of a human being, as commonly observed, is directly proportional to his possessions (material accumulations) and is inversely proportional to his wants.

Therefore, scientifically one can put Human Happiness

$$= k \times \frac{\text{Possessions}}{\text{Wants}}$$

Where k is a constant of proportionality, depending at the most on non-significant factors.

Western way for increasing human happiness is to increase the possessions only. This, though correct, is only a part of the truth. The Bhartiya (Hindu/Indian) interpretation of human happiness, which is very well imbedded in the minds of all Indians, covers up the western interpretation. This is, human happiness can be increased by increasing Possessions (numerator) and by decreasing Wants (denomination), with more emphasis on the later factor. The above formula well reflects this viewpoint and so the Bhartiya interpretation is scientific. For achieving infinite happiness, western way is only to get infinite possessions while the Bhartiya way is to control (decrease) the wants (denominator) to zero. Clearly this can bring infinite happiness in one's life with whatever little one possesses.

8

Scientific and Technological Developments

Scientific and Technological Development in India, may be summarized as follows :-

Period	*Scientific and Technological Developments*	*Other details (Places etc.)*
150000-25000 B.C.	The Early stone Age (Early Palaeolithic)—Chopper-chopping tool culture.	The Punjab, Peninsular India (excepting extreme south India)
25000-5000 B.C.	The Middle Stone Age (Middle Palaeolithic)—Predominance of flake tools, scrappers, points and borers etc.	—do—
5000-3000 B.C.	The Late Stone Age (Mesolithic) —Predominance of microliths, flakes, blades, lunates, scrappers, borers, chisels, triangles, trapezoids and drills etc.	Gujarat, Madhya Pradesh, Maharashtra, Mysore, Tamil Nadu (Tinnevelly) and West Bengal (Birbanpur) etc.
3500 B.C.	Neolithic Age	Baluchistan
2300-1750 B.C.	Harappan culture— Copper-bronze technology *cire perdue* method; wheell-made; decorated and glazed pottery; settled agriculture wheat and barley, domestication of animals; drainage and bath, burnt brick and mortar constructions;	Baluchistan, Sind, Punjab, Rajputana and Seurashtra.

Period	*Scientific and Technological Developments*	*Other details (Places etc.)*
	grid system of town planning; spinning and weaving; measurement and computational techniques.	
2000 B.C.	Some Neolithic settlements; agriculture; cave-drawing and paintings, depicting animals; handmade and wheel-made pottery.	Andhra, Karnatak, Bengal and Kashmir
1800 B.C.	Some Chalcolithic settlements; use of copper tools; Black/Red Ware; Malwa ware and Jarwe ware; spouted vessels.	Saurashtra, Rajputana, central, southern and eastern India
1800-1000	Ochre-coloured ware—copper-hoards.	Closed casting of metals
1500 B.C.	The *Rigveda*—concept of natural law; monistic idea concerning water; the *naksatra* system (lunar mansions) of marking ecliptic, beginnings of calendes system; knowledge of diseases and cure; agricultural practices, use of plough, wheat and barley; fermentation methods; use of horse.	Earliest literary Composition; Punjab and Kashmir regions
1000 B.C.	The *Yajurveda*—series of 27 or 28 *naksatras* headed by *Krittika*, number names on the decimal scale up to 10^{12}; agricultural practices, mentioning of rice.	Western U.P.
1000 B.C.	The *Atharvaveda*—astronomical knowledge; details of *naksatras*, method of intercalation; details of medical knowledge and practices; lists of different plants and animal.	Concept of *prana* as the sustainer of life; some parts of *Atharveveda* seem to be earlier

Period	*Scientific and Technological Developments*	*Other details (Places etc.)*
1000-600 B.C.	The *Brahmanas*, *Aranyakas* and *Upanisads*—astronomical ideas, cosmic cycle; beginnings of mathematical series (A.P. and G.P.); more anatomical and physiological knowledge; doctrine of *pancabhutas*; more elucidation of the world of the living and nonliving.	These ideas later influenced the Greeks
	Painted-Grey ware—in association with iron.	A deluxe pottery mainly in northern and north-western parts of India
	Production and use of Iron.	In small open-hearth furnaces
	Agricultural practices—rotation fallowing method to increase the soil fertility.	
600-400 B.C.	Northern Black-Polished ware, associated with the use of iron; making of steel.	Mainly in Eastern India; later spread to other parts of India
	Glass objects at Taxila.	Bhir mound at Taxila
	Codification of medical knowledge into the *Ayurveda*.	
	Vedanga Jyotisa—five-year cycle; further elaboration of calendarical knowledge.	*Naksatra* system continued to be the basis
	Sulba-sutras—beginnings of Geometry: anticipation of Pythagorean theorem; development of irrational-numbers' knowledge.	As aid to construction of sacrificial altars

Period	*Scientific and Technological Developments*	*Other details (Places etc.)*
	Early ideas of *Vaisesika; Samkhya* and Mimamasa, of the Budha, Jaina and the Carvaka; Physical concepts; atomism, space, time, motion, sound.	As part of the religio-philosophitical position.
400 B.C. —400 A.D.	The *Ayurvedic* treatises — the Caraka and Susruta *Samhitas*, containing the *tridosa* theory, physiology, anatomy, pathology, therapeutics and surgical practices.	Emphasis on herbal medicine; skill in laparatomy, lithotomy and rhinoplasty
	Development of the orthodox philosophical sutras; the Jaina, the Budha schools; extension of the doctrines of five elements, space, time and sound.	Respective epistemological positions made specific
	The *Arthasastra* of Kautilya; mining, metal working, agriculture and irrigation.	
	Bhagvati-sutra; Tattvarthadhigamahsutra of Umasvati; atomisms, classification of living and non-living.	
	Restatements of astronomical ideas; adoption of zodiacal system; knowledge of the motion of planets.	May be Greek or Babylonian influences
	Progress in mathematics; permutations and combinations—*meruprastrara* and the early binomial ideas.	Pingala's *Chandah-Sutra*
	Widespread use of iron; construction of Sudarsana Lake.	Use of bellows in extracting iron.

Period	*Scientific and Technological Developments*	*Other details (Places etc.)*
	Glass objects at a number of places.	Foreign influences —Roman, at Taxila and Tamilnadu
A.D. 400- A.D. 500	*Nyayabhasya* of Vatsyana—atomicism further extended; views on vision and propagation of sound; classification of animals and plants; impetus theory.	
	Padarthadhamasamgraha of Prasastapada; atomism; time, space, motion, sound.	An independent work resembling vaisesika categories
A.D. 400-500.	*Aryabhatya*—Theory of the rotation of the earth, epicyclic theory for planetary motion; values of sines and pie π; alphabetical system of expressing decimal place-value notation; interminate equation of the first order; extraction of square and cube roots.	Growth of the Indian decimal pleace-value system
	Metal workings; art of jewellery; Iron pillar now near Kutab Minar, Delhi.	Made of Wrought iron (99.72%)
	Copper statue of Budha from Sultanganj, Bihar (now in Birmingham Musuem)	Cast in two layers
	Sophisticated ceramic ware.	On the Indo-Gangetic plains
A.D. 500-600	*Panchasiddhantika* of Varahamihira: the five Siddhantas—*Saura, Paulisa, Romaka. Brahma* and *Paitamaha*; concept of mahayuga (4,320,000 years); equinoxes in the *Suryasiddhanta.*	The *Suryasiddanta* emerged as the best and the most accurate

Period	*Scientific and Technological Developments*	*Other Details (Places etc.)*
	Brhat Samhita of Varahamihira—Chemical processes; plant and animal classifications.	Encyclopaedic work
	Amarakosa—Classification and synonyms of plants and animals, mineral and metals.	Lexicon
	Budhist logic and Jaina views.	Problems of mattor elucidated.
A.D. 600-800	Bramagupta (Astronomer and mathematician) —*Brahamasphutasiddhanta* and *Khandokhadyaka*; Lemma for solution of the interminate second order equation; formula for the sum of nth terms of A.P.; rules for the area of cyclic quadiilateral and for the volume of a prism, etc.	Both translated into Arabic in the 8th century A.D., and named as *Sindhind* and *Arkand*
	Nyaya-vartika of Udyotakara; more elucidation of atomic views.	
	Rugvinscaya of Madhava; diagnostic methods.	Also called *Madhavanidana;* translated as Arabic and titled as *Badon*
	Astangahrdaya of Vagbhata—an authoritative compilation of the Ayurvedic knowledge based on the early works.	Changed in Arabic and titled as *Astankar*
A.D. 800-1000	*Ganitasarasamgraha* of Mahavira: Operations involving zero and Summation of n terms of G.P.	Mysore
	Krsi-Parasara and *Vrksayurveda.*	Manuals on agriculture and botany

Period	*Scientific and Technological Developments*	*Other details (Places etc.)*
	Alchemical practices; *Rasahrdaya* of Govinda Bhagavat.	As part of tantrik practice
	Siddha system of medicine.	Tamilnadu; mainly mineral medicines
	Munjala's elucidation about procession of equinoxes.	In competition with earlier libration concept.
A.D. 1000-1200	Sridhara's method of solving quadratic equations.	
	Siddhantasironani of Bhaskara II: astronomical and mathematical work in four parts; *cakravala* method for rational integral solutions of the indeterminate equation of the second order; geometric proof of the Pythagorean theorem; root idea of differential calculas; elaboration of epicyclic-eccentric theories for planetary motions; analysis of the motion of the sun by considering longitudinal changes.	Influenced later astronomers and mathematicians; some commentaries followed; represents the height of Indian mathematics and astronomy
	Manasollasa of Somadeva; alchemy; perfumery; iron-casting.	
	Knowledge of paper-making.	Came possibly from Nepal and Arabia.
A.D. 1200-1500	*Sarangdhara Samahita* – Opium and its materia medica, pulse and urine examination for diagnosis.	Foreign influences
	Rasasastra texts: *Rasarnava*, *Resaratnakara*; *Resaratnasamuccaya* etc.; classification of substances; experimental techniques.	Skill in Chemical processes

Period	*Scientific and Technological Developments*	*Other details (Places etc.)*
	Narayana Pandita—further refinement of arithmatic and algebraic operations.	
	Paramesvara – commentator on astronomical and mathematical works Pyrotechnics.	Belonged to Kerala. Production Centres in South India
A.D. 1500-1600	Ganesa Daivajna – commentator on astronomical and mathematical works.	Maharashtra
	Use of mercurial and non-mercurial compositions in medicines; Bhavaprakasa: materia medica, treatment of syphilis; Gunpowder and guns.	Largely used during the Mughal period
	Advent of the Portuguese physician Garcia da orta, introduction of new economic plants.	Publication of Garcia's Colloquies (1565)
A.D. 1600-1700	*Tuzuk-i-Jahangiri*—about animals and plants. Advent of the Dutch, French and the British, study of Indian flora.	Commercialisation
1723-27	Construction of Jantar Mantars at Delhi, Ujjain, Mathura, Banaras, Jaipur by Maharaja Sawai Jai Singh II.	Huge masonry astronomical instruments
	Samrat Siddhanta of Jaganatha.	Translation of the Arabic version of Ptolemy's *Almagest*
	Rekhaganita of Jaganatha.	Translation of the Arabic version of Euclid's *The Elements*

Period	*Scientific and Technological Developments*	*Other details (Places etc.)*
1737	d' Anville's first map of South India, his map of India, *carte de l' Inde*.	Based on Maragha school of astronomy and Jesuit sources
1755	Botanical investigation of Koenig in South India.	The collection was sent to the University of Lund in Sweden.
1764	Ganges river course Surveyed by Rennell.	Organised by East India company.
1781	Madrasah at Calcutta.	Established on the initiative of Warren Hastings.
1783	First Map of Hindoostan by Rennel.	
1784	The Asiatic Society founded at Calcutta.	The Founder President was William James
1785	First paper (in Persian) presented with title—The care of the Elephantiasis and other Disorder of the Blood.	Translated and presented by William Jones himself
1787	Royal Botanic Garden at Sibpur, Calcutta.	Robert Kyd (first Honorary Superintendent
1791	*Samskrta Pathasala* at Banaras.	By the efforts of Janathan Duncan
1792	Madras Observatory established.	By Michael Topping
1794	Survey School at Madras.	Beginnings of trigonometrical Survey
1795	Commencement of the publication of the *Flora Indica*.	Three volumes in 1795, 1802 and 1819

Period	*Scientific and Technological Developments*	*Other details (Places etc.)*
1800	Establishment of Trigonometrical survey Department at Madras.	
1813	Introduction of a clause (in East India Company's Charter) for spending on *lac* rupees per year for the promotion of knowledge of sciences among people of India.	Beginning of British interests in educating the Indians in Science.
1817	Establishment of Mahavidyalaya (Hindu College) at Calcutta.	Public patronage of English education.
1822	Preparation of the Atlas of India on the quarter inch scale.	
1832	Publication of *Journal of the Asiatic Society* of Bengal.	
1835	Calcutta Medical College.	
1843	Medical School at Madras	
1845	The Grant Medical School at Bombay.	
1847	Engineering Institution at Roorkee.	Later became Thomson Engineering College.
1851	Establishment of the Geological Survey of India.	Thomas Old ham's efforts.
1851	The fiirst telegraph line between Calcutta and Diamond Harbour	By William O'Shaughnessy
1853	The first railway line laid.	Near Bombay
1854	Charles Wood's Despatch for the creation of the Universities	On the model of the London university
	Engineering School at Poona.	
1856	Engineering College at Sibpur, Calcutta.	

Period	*Scientific and Technological Developments*	*Other details (Places etc.)*
1857	Establishment of the first three Universities at Calcutta, Bombay and Madras.	Only affiliating and examining bodies
1859	Civil Engineering College at Madras.	
	Establishment of Archaeological Survey of India	Cunningham as the Archaelogical Surveyor
1867	Indian Museum came in to being at Calcutta.	Gallaries thrown open to be public in 1878
1875	Establishment of India Meteorogical Department.	
1876	Foundation of the Indian Association for the Cultivation of Science.	By Mahendra Lal Sircar through public endowments.
1881	Publication of the first mathematical paper of Asutosh Mukherji.	In the *Messenger of Mathematics*
1884	Centenary of the Asiatic Society of Bengal; paper published-500 in mathematical and physical sciences, 560 in Zoology, 320 in Botany.	Calcutta
1890	Imperial Bacteriological Laboratory at Poona.	Shifted in 1893, to Mukteswar
	Botanical Survey of India formed.	George King appointed as the first Director
1895	Foundation of Solar Physics Laboratory at Kodaikanal.	Working started in 1900
	J.C. Bose's first scientific paper on the polarization of electric waves by double refraction.	Published in JASB

Period	*Scientific and Technological Developments*	*Other details (Places etc.)*
1896	Plague Research Laboratory at Bombay, whose name was changed (in 1906) to Haffkine Institute.	Haffkine was appointed as the first Director
	P.C. Ray's work on mercurous compounds.	Published in JASB
	Recommendation of the Royal Agricultural Commission emphasized research on agriculture.	Establishment of Imperial Agricultural Research Institute at Pusa (Bihar), in 1903.
1897	J.C. Bose's lecture at the Royal Institute, London, with his own apparatus, the Electric Radiator. He preceded Marconi in discovering Wireless Telegraphy.	
1900	J.C. Bose's paper, 'On the Generality of the Molecular Phenomena produced by Electricity on Living and Non-living substances.'	Paper was read at the International Congress in Physics at Paris
	P.C. Ray's analysis of a number of rare Indian minerals to discover in them some of the missing elements in Mendeleef's Periodic Table.	Published in the Memoirs of the Geological Survey of India
1914	Indian Science Congress Association formed with the Hon'ble Justice Sir Asutosh Mookherjee as its first President.	Calcutta
	J.C. Bose designed High Magnification Crescograph to measure slow growth rate of plants, which earned him FRS in 1920.	

Period	*Scientific and Technological Developments*	*Other details (Places etc.)*
1914-1919	S. Ramanujan (FRS, 1918) published 21 research papers and solved many intricate mathematical problems such as partitioning of natural numbers and solution of the famous Waring Problem.	University of Cambridge
1917	Meghnad Saha (FRS, 1927) gave Theory of Thermal Ionisation; Epoch-making Saha's equation for degree of ionisation in a stellar atmosphere.	
1930	Sir C.V. Raman became the first Asian Nobel Laureate in Physics.	For his discovery *Raman effect* and *Raman Spectra*
1935	National Institute of Sciences formed which was later renamed as INSA.	Delhi
1936	Birbal Sahni (FRS, 1936) pioneering work in Indian Palaeobotany. He was elected President of the International Botanical Congress, Stockholm, 1950.	Lucknow
1940	CSIR formed with S.S. Bhatnagar (FRS, 1943) as its Founder Director.	
1941	H.J. Bhabha (FRS, 1941) gave Casacade Theory of cosmic-ray showers, and Vertor Theory of Meson.	
	Establishment of TIFR.	Bombay
	Establishment of Atomic Energy Establishment, which was later renamed as BARC.	Trombay
	Atomic Reactors Commissioned	Cirus, Rajasthan and Tarapur

Period	*Scientific and Technological Developments*	*Other details (Places etc.)*
1950	Establishment of National Physical Laboratory.	New Delhi
1958	S.N. Bose (FRS, 1958) work in Nuclear Physics got international fame. Bose-Einstein statistics has become an integral part of textbooks on modern physics. All nuclear elementary particles are are now categorised—*Bosons* and *Fermions*.	
1965	India developed the process for the manufacture of optical glass which is a closely guarded secret of about ten countries in the world, under the guidance of Dr. Atma Ram (who pioneered Glass Technology in India). He is the first Asian to become Honorary Fellow of the Society of Glass Technology, Sheffield.	
1971	M.S. Swaminathan (FRS, 1973) got Ramon Mogsaysay Award for Community Leadership and recognised as 'Scientist, educator and administrator towards generating a new confidence in India's agricultural capabilities. He has been the key figure in bringing the Green Revolution in Asia.	
1974	India's first peaceful nuclear explosion (under the guidance of Dr. Raja Ramanna).	Pokharan

Period	*Scientific and Technological Developments*	*Other details (Places etc.)*
1975	India stood the forth among the countries that supplied experts (538) to the United Nations Development Programme (1975).	
1980	By the end of 1980, the number of Indian scientists who have been honoured with FRS, has come around forty.	
1981	India has become the world's third largest community but is the fourteenth largest country so far as output in scientific literature is concerned.	

Bibliography

AGGRAWAL, V.S. — India as known to Panini

ANDERSON, R.S. — Building Scientific Institutions in India

ANIKEEK, N.P. — Modern Ideological Struggle for the Ancient Philosophical Heritage of India

AUROBINDO, SRI — On the Vedas

BAG, A.K. — Binomial Theorem in Ancient India (IJHS, 1—1966)

BALL, W.W.R. — A Short Account of History of Mathematics

BASHAM, A.L. — The Wonder that was India

BERILL, N.J. — Inherit the Earth

BERNAL, J.D. — Science in History

BHADURI, S. — Studies in Nyaya—Vaisesika Metaphysics

BHART KRSNA (Jagadguru Shankaracharya of Puri) — Vedic Mathematics (Sixteen Simple Mathematical Formulae from the Vedas)

BHASKARACHARYA — Lilavati (Translation by Colebrooke); Siddhanta Siromani

BISWAS, A.K. — Science in India

BOSE, D.M. — A Concise History of Science in India

BOSE, D.M. — Jagdish Chandra Bose

BOSE, J.C. — Response in the Living and Non-Living

BURKILL, L.H. — Chapters in the History of Botany in India

CAJORI, F. — A History of Mathematics

CAJORI, F. — A History of Physics

CARAK — Caraka Samhita (English translation in six volumes by S.G.K. Ayurvedic Society, Jamnagar)

CLARK, W.E. — The Aryabhatiya of Aryabhata

COLEB ROOKE, H.T. — Algebra with Arithmatic and Mensuration from the Sanscrit of Brahmegupta and Bhascara

DAMPIER, W.C. — A History of Science

DASGUPTA, S.N. — History of Indian Philosophy

DATTA, B.B. & SINGH, A.N. — History of Hindu Mathematics

DATTA, B.B. — The Bakhshali Mathematics

DATTA, B.B. — The Science of Sulba

DES PANDEY, BANI — Universe of Vedanta
DUTT, U.C. — Materia Medica of the Hindus
EINSTEIN, ALBERT — Essays in Science
FILLIOZAT, JEAN — The Expansion of Indian Medicine Abroad
FILLIOZAT, JEAN — History of Science : ancient and mediaeval
GOLDSMITH, M. & MACKAY — The Science of Science
GRAYSON, H. — The Changing Concepts of Science
GURUDATT — Science Aur Ved
HALDANE. J.B.S. — Science and Indian Culture
HAZRA, R.C. — Studies in the Puranic Records on Hindu Rites and Customs
INFA Publication — Who's Who
JACOBI, H. — On the Dating of Rgveda (IA, 23,154-59, 1894)
JAGGI, O.P. — A Concise History of Science
— Scientists of Ancient India and their Achievements
— Indian System of Medicine
JAGJIT SINGH — Some Eminent Indian Scientists
JAYARAM, K.C. — Some Observations on the knowledge of the Ancient Hindus regarding Animal Life during the Early Jain and Buddhist Period (C. 600 B.C.), JZSI, 2, 1950
JOSHI, R.V. — Stone Age Industries on the Damoh Area (MP) (AI, 17, 1961)
JAIN, N.K. — Revival of Scientific Studies in India (Hinduism, London, 82, 1978)
JAIN, N.K. — History of Medicinal and Biological Sciences (Hinduism, 87, 1979)
JAIN, N.K. — Mathematics and Astronomy in India (Manthan of Deendayal Research Institute, 2, 2, 1979)
JAIN, N.K. — Development of Scientific Method (School Science of NCERT, XVII, 1, 1979)
JAIN, N.K. — Homi Jehangir Bhalha, School Science (XVI, 3, 1978)
JAIN, N.K. — 'Takshashila Visvavidyalaya', Nalanda Vishvavidyalaya' (Bhavan's Journal—XXIV, 10,1977; Sept. 1978)
JAIN, N.K. — Naya Ganit Ka Nayapan, (Vigyan Pragati of CSIR. 29,4,1979)
JAIN, N.K. — Logic of Science, Patriot (daily), Dec. 1978
JAIN, N.K. — J.C. Bose; Meghned Saha; C.V. Raman; Jayant Narlikar; P.C. Ray; S.S. Bhatnagar; Age of the Universe (all in Yuva Bharati of Vivekanand Rock Memorial Committee, Madras.)

KAYE, G.R. — The Astronomical Observatories of Jai Singh, (Archaeological Survey of India, Vol. XL, Calcutta, 1918)

KAYE, G.R. — The Bakhshali Manuscript

KEITH, A.B. — Vedic Calender (JRAS, 627—40, 1914)

KEITH, A.B. — Indian Logic and Atomism

KERN, H. — The Brht Samhita of Varahimihira

KOTHARI, D.S. — Science and Dharma

KOTHARI, D.S. — Nuclear Explosives and their Effects

KOTHARI, H. — Who's Who in Indian Science

KRISHNASWAMY — Stone Age in India (AI, 3, 1947)

LAL, B.B. — The Direction of Writing in the Harappan Script, (Antiquity, 40, No. 157, 52—55, 1966)

LAL, B.B. — Excavations at Kalibangan, (New Light on the Indus Civilization, CF, 34, 1967)

LEVEY, MARTIN & PETRUCK — Principles of Hindu Reckoning (Translation of *Kitab Fi Usul Hisab al Hind* by Kushyar Ibn Lalban)

MACKAY, E.J.H. — Further Excavations at Mohenjo-daro (an official account of archaeological excavations of Mohenjo-daro, carried out by the Govt. of India between the years 1927—31, 2 Vols.; Delhi, 1937-38)

MAHESHWARI, P. & KAPIL, R.N. — A Short History of Botany in India (JUG, 9, 1—34, 1958)

MAJUMDAR, R.C. — History and Culture of Indian people (Bhartiya Vidya Bhavan, 1947—61)

MARSHALL, J. — Mohenjo-daro and the Indus Civilization (an official account of archaeological excavations carried out by the Govt. of India between the years 1922 and 1927, 3 vols., London, 1931)

MAXMULLER — India what can it teach us

MEHTA, D.D. — Some Positive Sciences in the Vedas

MISHRA, UMESH — The Conception of Matter according to*Nyaya Vaisesika*

MOOKERJI, R.K. — Hindu Civilization

MORLEY, GRACE — A Brief Guide to National Museum

MUKERJI, B. & BOSE, P.K. — Life Sketches of General Presidents, ISCA

MUKHOPADHAYAYA, G.N. — History of Indian Medicine

MUKHOPADHYAYA, G.N. — The Surgical Instruments of the Hindus

PANIKAR, K.M. — A Survey of Indian History

PARKASH, S. — Founders of Sciences in ancient India (The Researeh Institute of Ancient Scientific Studies, New Delhi, 1965)

PIGGOT, STUART — Some Ancient Cities of India

PIGGOT, STUART — Prehistoric India to 1000 B.C.

POINCARE, H. — Science and Method

POPPER, KARL — The Open Society and its Enemies

RAY, P.C. — History of Hindu Chemistry

RAY, P. & GUPTA, H.N. — Caraka Samhita (a Scientific Synopsis), NISI

REEVES, RUTH — Cire Perdue Casting in India

ROY, M. — Scientific Information in the Ramayana (BNISI, 21, 58—66,1963)

RUSSEL, BURTRAND — The Scientific Outlook

SACHAU, E. — Alberuni's India

SANKALIA, H.D. — Some Aspects of Prehistoric Technology in India

SARKAR, B.K. — The Hindu Achievements in Exact Science

SARMA, K.V. — Lilavati of Bhaskaracarya with Kriyakramakari of Shankara and Narayana

SASTRI, T.S. KUPPANNA — The Vasistha Sun and Moon in Varamihira's Pancasiddhantika

SASTRI, T.S. KUPPANNA Mahabhaskariya of Bhaskaracarya

SEAL, B.N. — The Positive Sciences of the Ancient Hindus

SEN, S.N. — Transmission of Scientific Ideas between India and Foreign Countries in Ancient and Medieval Times (BNISI, 21, 8—30, 1963)

SEN, S.N. — An estimate of Indian Science in Ancient and Medieval Times (Scientia, March-April, 1966)

SEN, N.R. — Progress of Mathematics in India (1939—50)

SHASTRI, V.N. — Sciences in the Vedas

SHAMASÀSTRY, R.— The Vedic Calender, (IA, 18, 26—32, 45, 71, 1912)

SIVARAMAMURTI, C.— Harappan Art

SOMERWILLE, JOHN — The Way to Science

SRINIVASA, G. — The Existentialist Concepts and the Hindu Philosophical Systems

SUBBARAYAPPA, B.V. — An Estimate of the Vaisesika Sutra in the History of Science (IJHS, 2, No. 1, 21—24, 1967)

SUBBAREDDY, D.V. — Jeevaka (Ind. J. Hist. Med. 31—37, 1958)

SWAMI, RAMA TIRTH — Mathematics and Vedanta (Vol. IX of the complete works of Swami Rama Tirth)

SWAMI, RANGANATHANANDA — Vedanta and Science

SWAMI, VIVEKANANDA — Science and religion

TAYLOR, F.S. — Science Past and Present

TITIEV, MISCHA — The Science of Man

VATS, M.S. — Excavations at Harappa (2 Vols., Delhi, 1938—40)

VIDYALANKAR, ATRIDEV — Ayurveda Ka Brihat Ithas

WATTERS, T. — On Huan Chwang's Travels in India (A.D. 629—645)

WIGHTMAN — The Growth of Scientific Ideas

WOODS, H.J. — Yoga System of Patanjali

ZIMMER, H.R. — Hindu Medicine

Index

Ahimsa, 128
Akash, 1
Aksapada, 70
Alberuni, 40
Alchemy, 39
Amarat, 39, 40
Anattihika, 51
Ancient Astronomy, 33-35
Anu, 4, 41
Anumana, 71
Apa, 3
Applications of Science, 131-2
Approach to Life, 67
Aptavakya, 71, 72
Ardhajya, 36
Aryabhate, 34-35
Aryabhatiya, 34-35
Asat, 2
Asiatic Society, 63, 81, 101
Atharvaveda, 42, 48
Atman, 68
Atma Ram, 121-124
Atreya, 50, 57-58
Attihika, 51
Ayurveda, 23, 48, 51, 52

Bakshshali Manuscript, 30-31
Bardeen John, 22
Basu Vijnan Mandir, 84
Bandhayana Sulba Sutra, 31, 32
Bernal, J.D., 22
Bhabha, H.J., 93-95
Bhagwati, J., 66
Bharat Ratna, 92
Bhardwaja, 50
Bhaskaracharya, 36
Bhatnagar S.S., 102-104
Bhoja, 44
Bhuta, 3
Bhutadi, 3
Biology, 44
Borlaug N.E., 110
Bose J.C., 80-85, 101
Brahmagupta, 25, 36
Brahman, 69
Brahamanas, 25
Brahma day, 1
Brain-drain, 64-66
Brahmi Numerals, 27
Brahmasphutasiddhanta, 36
Buddha, 71

Cakrapanidatta, 50
Cascade Theory, 94
Chandrasekhar, S., 65
Chanakya, 57
Charaka, 48, 49
Charaka Samhita, 49
Chaturyugas, 7, 34
Chatterjee A.N., 64
Chemistry, 38-44
Chopra, S.R.K., 13-14
Cire-perdue process, 56
Civilizations, 15
Coherrer, 82
Cotton-earliest evidence, 56
Creation of the Universe, 1-9
    Earth, 10-11
    Man, 11-14
Crescograph, 83, 84

Dandamis, 60
Death, 69
Decline of Indian Science, 62-63
Deshpande Bani, 23
Dhanvantri, 50

Dharma, 125-128
Dhatuvidh, 43
Dridhabala, 50
Dwara Pandits, 59

Earth, 10-15
Einstein Albert, 21, 91
Ekadhikena Purena Sutra, 38
Electric Engineer, 82
Electric Radiator, 81, 82
Encylopaedia Britannica, 85
Evolutionary Charts, 12

Fatigue, 82, 84
Fergusson, 43
Fi-Hien, 24, 61
Filliozat Jean, 24

Gandak ka attar, 44
Ganitajyotisha, 33
Gates Dr., 69
Ghosh Sisir Kumar, 63
Gita, 1, 23, 24
Glass technology, 121-123
Goldstucker, 21
Gotama, 42, 70
Great Centres of Learning 57-62
Gunas, 3
Gwalior inscriptions, 27, 28

Haldane J.B.S., 66
Harappa, 26, 54-57
Henry Verahuk, 69
Hertz, 81
Himsa, 128
Horrors of Science 133-137
Hoyla Fred, 98
Hsuan Tsang, 62
Human Happiness, 138
Hunter William

Impact of Science, 129-130
Indus Inch, 26
Indus Valley Civilization, 26, 54-57
Ion, 87
Ionisation, 87
Irritability, 84

Jiva, 67
Jivika, 50, 58-59
Jyotisa, 26
Jyotisha Vedariga, 33

Kalpa, 1
Kalpasutras. 25
Kapha, 48
Kapila, 3, 24
Kanada, 41
Karmas, 68
Katha Upnisad, 69
Khalifa Harun Al Rashid, 51
Khandakhadyaka, 36
Kharoshi Numerals, 27
Khorana Hargobind, 65
Killer W.J., 69
Kothari, D.S., 95-97
Kotijya, 36
Kshiti, 3
Kutab Minar, 43

Laplace, 21
Lenin, 21
Lilavati, 36
Limitations of Science, 137
Lord Kelvin, 81

Madhavekar, 50
Mahabharata, 48, 80, 90, 126
Mahayuga, 7, 8, 34
Maheshwari, P., 117-121
Makra-dhvaja, 43
Man on earth, 11-15
    in India, 13
Manaka, 51
Mandelssohm, Kurt, 66
Manu, 7, 8
Manusamriti, 19, 125
Marconi, 81
Mathematics, 25-38
Max Muller, 21
Maxima and Minima, 63
Mecdonell, 42
Medhatithi, 30
Medicine 44-47

Meson, 94
Milind, 22
Mishra Bhave, 50
Mitra Rajendralal, 63
Moksa, 68
Mohenjo-daro, 26, 54-57
Moksa, 68
Mukherji Ashutosh, 63, 64, 90

Nacula, 50
Nagarjuna, 23, 40, 43
Nagasen, 22
Nalanda :
Brother, 62
Vishvavidyalaya, 48, 61-62, 85
Narlikar J.V., 74, 97-100
Nasadiya Sukta, 2
Neem tree, 57
Nemalite crystal, 81
Newman, J.R., 37
Nirvana, 68
Nivedita, 82
Nobel Prize, 92
Noise, 136
Non-living, 80, 84
Nyaya Sutra, 71

Palaeobotany, 114-116
Panchasiddanta, 35
Panini, 57
Paras Pathar, 38, 39, 40
Parmatman, 68
Patanjali, 50
Phlogiston, 79
Planck, 42
Pitta, 48
Polarise, 81
Pollution, 134-136
Popper Karl, 128
Prakriti, 1, 3
Pralaya, 1
Pratyaksha, 71
Proconsul, 46
Protoplasm, 11
Protozoon, 12
Ptolemy, 34, 35
Pythagoras, 24, 25, 32, 33

Rajas, 3
Ramachandra, 63
Raman, C.V., 89-93
Raman Effect, Spectra, 91
Ramanna Raja, 107-109
Ramanujan Srinivasa, 85-87
Ramayana, 48, 80, 90
Rasaratnasamuchchaya, 40
Rasayana, Rasaratnakara, 40
Ray, P.C., 100-102
Rebirth, 68
Resonant Recorder, 84
Rest, 83
Revival of Scientific Studies, 63-67
Rigveda, 1, 2, 4, 10, 20, 42, 43
Roy, Raja Rammohan, 63
Russel Burtrand, 125

Saha Meghnad 87-89, 95, 96
Sahadeva, 50
Sahni Birbal 114-116
Samhitas, 25
—Narada, 79
Samkhyana, 26
Sankhya philosophy, 3
Sat, 2
Satapatha Brahmana, 32
Sattva, 3
Science/Scire/Scientia, 16-18, 70, 125
Scientists, 80-124
Science and Culture, 89
Science and Dharma, 125-128
Science in India, 16-48
Scientific Developments, 139-150
Scientific Method, 70-79
Scope of Science, 130
Sebokht, 24
Seshadri, T.R., 104-107
Sleep, 84
Shankaracharya, V. Sareswati, 37
Siddhanta Siromani, 36
Silajit. 56
Sircar Amritlal, 90
—Mohendralal, 63
Sodihtra, 50
Soma, 42
Stratigraphy, 57

Stewansion Ian, 68
Sukraniti, 44
Sulbasutras, 25, 31, 33
Sura, 42
Susruta, 49
Susruta Shalya Tantra, 49
Susruta Samhita, 48; 49
Swaminathan, M.S., 109-114

Tagore Dwarkanath, 63
Rabindernath, 84
Taittiriya Samhita, 32
Taksashila Vishvavidyalaya, 48, 57-61, 85
Tamas, 3
Tanmatras, 3
Tattva-thadhigamasutra, 50
Technological Developments 139-150
Teja, 3
Test-tube Baby 132-133
TIFR, 74
Titmus Richard, 65
Tourmaline crystal, 81
Toy-carts, 56
Tridosa, 48, 49
Truncation, 87
Tsungnachho, 52

Umasvati, 50
UNCTAD, 65, 66
UNDP, 64
Universe Creation, 1-9
  Age 7-9
Upadhyaya Deendayal, 125
Upamana, 71
Upanishads, 48

Vagbhata, 49, 50
Vaiseshika Sutras, 41
Varahmihira, 35
Vata, 48
Vayu, 3
Veda Rigveda, 1, 2, 4, 10, 20, 42, 43
  Yajurveda, 20,
  Atharvaveda, 20, 42, 48
  Ayurveda, 20, 23, 48, 51, 52
Vedangas, 25
Vedavyas, 126
Vines, 84
Vivekananda, Swami, 84

William Dellafar, 66
Worel-numerals, 29
Yejurveda, 10, 20
Yugas, 7, 8
Zimmer, 49

CORRIGENDUM

Page No.	*Line No.*	*For*	*Read*
5	14	Copernicus	Copernicus
7	4	v	V
7	5	18600/19 xd	186000/19
10	21	in Vedic	Vedic
10	27	365°256	365·256
11	3	reasons	seasons
11	35	Protoplasm	Protoplasm.
13	27	to million	million to
19	19	orign	origin
21	10	odenburg	Odenburg
21	19	methematician	mathematician
22	6	There	"There
23	5	Sulabsutra	Sulbasutra
24	6	सिध्दाना	सिध्दानां
24	16	mathamaticians	mathematicians
31	6	) A	), A
31	26	800-6000 Bc	800-600 Bc
32	4	पाश्वँ	पार्श्व
32	8	lenth	length
32	10	an are area	an area
33	31	synodie	synodic
33	34	trithis	tithis
34	21	between 17	between Feb. 17
35	5	Pattiputra	Patliputra
35	5	athat	that
36	32	त्रिपष्टया	त्रिषष्टया
37	11	ghgat	ghaat
37	11	heat	haet
40	5	InIndia	In India
41	34	indentical	identical
46	26	both and ape	both man and ape

Page No.	*Line No.*	*For*	*Read*
46	27	authropoid	anthropoid
52	39	Andreas,	Andreas
54	37	umerian	Sumerian
67	39	ajiva	nirjiva
71	12	fact	a fact
82	4	discover	discovery
82	16	rays	waves
88	13	seience	science
88	26	Joliot Curie and	and Joliot Curie,
90	13	theory	theory of
93	3	x-rays	x-rays.
98	27	(1973).	(1973)
98	28	Universe.	Universe,
99	11	gnorance	ignorance
102	22	if	of
103	38	Sciences. during 1947-48	Sciences, during 1947-48.
104	3	administrative	administrator
108	31	Indians	Indian
109	20	1952-53	During 1952-53
109	23	Wiscosin	Wisconsin
110	40	Barlaug	Borlaug
111	33	Mogaysay	Mogsaysay
129	24	science	so science